The Engineer

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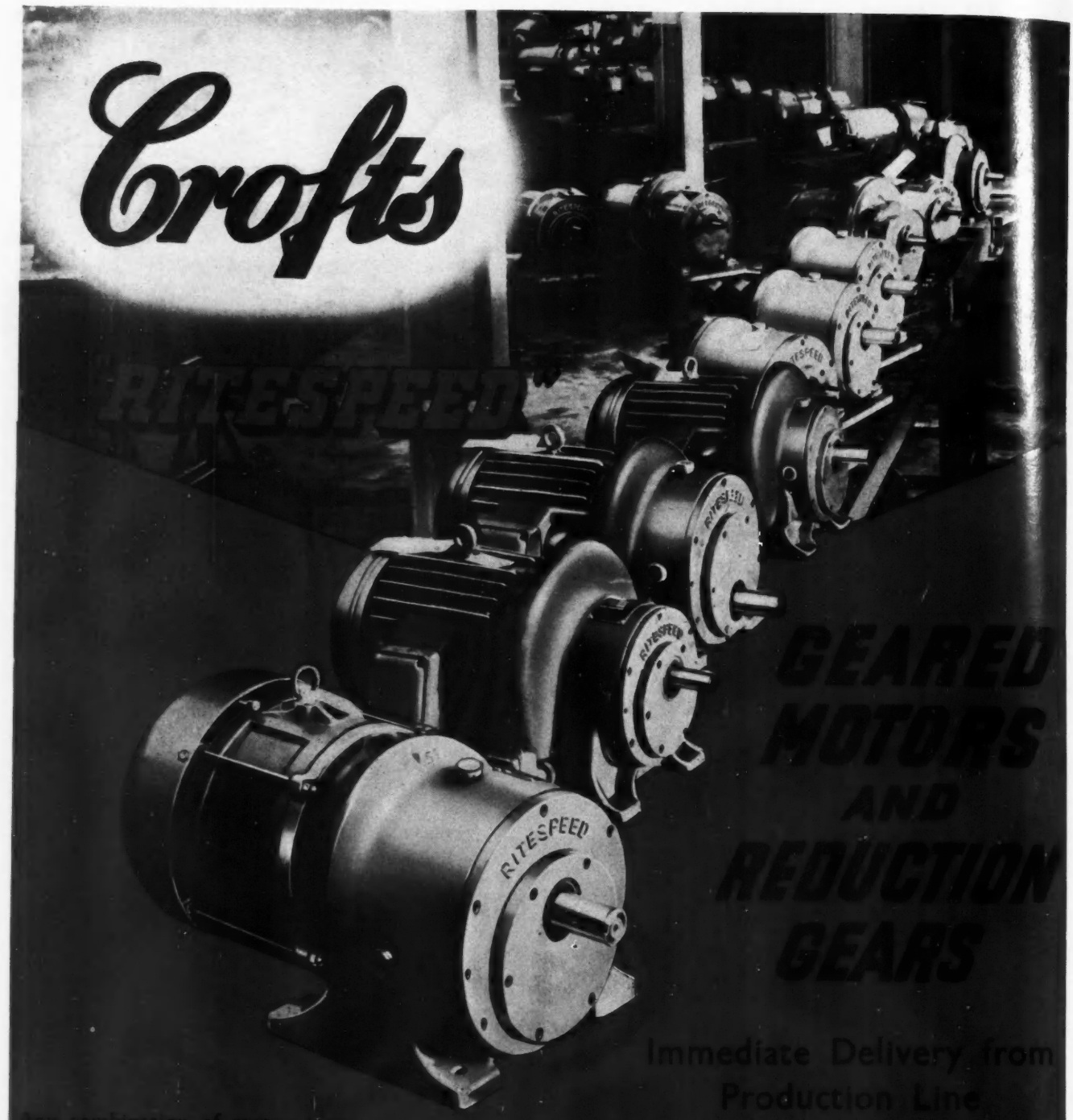
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THE ENGINEER

APRIL 22, 1955

The Budget

THE Chancellor of the Exchequer, Mr. R. A. Butler, presented his Budget for 1955 to the House of Commons on Tuesday afternoon. The main proposals include a reduction in the standard rate of income tax from 9s. in the pound to 8s. 6d., with reductions of 3d. in the lower income tax rates. In addition, personal allowances and children's allowances are to be increased. There are also proposals for reducing from 50 per cent to 25 per cent the purchase tax on certain non-wool textile materials. The Chancellor said that he did not feel justified this year in making any general reductions in indirect taxation. The announcement of the Budget proposals was prefaced by the Chancellor's customary survey of the economic situation. He recalled that last year he had budgeted for a small surplus of £10,000,000, and actually a surplus of £423 million had been achieved. Below the line receipts for the year were in accord with the estimate of £191 million, but expenditure, at £692 million, was £94,000,000 bigger. This year, the Chancellor stated, he was budgeting for a surplus of £282 million. Talking about the country's "external prospects," the Chancellor said that if we were to be competitive, above all in price, it was essential to combine a policy of incentive and expansion with continued restraint in the demands made on that expansion for personal satisfaction. As to home prospects, the Chancellor estimated that the increase in home demand should be appreciably less than it had been in the last two years. On the other hand, the scope for increased production was at least as great as it had been in the past, if not greater. In each of the last two years, output per man in industry had risen very encouragingly. Throughout the same period, the Chancellor added, new projects of investment had been put in hand, while industry had been showing itself increasingly aware of the need to raise productivity, and increasingly eager to explore the possibilities of new techniques and methods of production.

Retirement of Lord Weir

THIS week it has been announced that the Viscount Weir of Eastwood, G.C.B., has intimated his intention to retire from office as director and chairman of G. and J. Weir, Ltd., at the forthcoming annual general meeting. The board feels that Lord Weir's long and valued association with the company, extending over fifty-seven years, should be recognised, and, therefore, proposes to ask the stockholders to approve his appointment as the first honorary president of the Weir group of companies. In addition to the long years of work with his firm, Lord Weir has a distinguished record of public service. In the first world war, he was Scottish Director of Munitions, Controller of Aeronautical Supplies, and subsequently Director General of Aircraft Production at the Ministry of Munitions. From April to December, 1918, Lord Weir was President of the Air Council, and in the following year he served as chairman of the advisory committee on civil aviation. When the second world war started in 1939, Lord Weir became Director General of Explosives at the Ministry of Supply, and in 1942 he was appointed chairman of the Tank Board. Other offices held by Lord Weir include those of honorary president of the British Employers' Confederation and president of the Royal Scottish Automobile Club. In recent years Lord Weir has made generous donations to further the work of several professional engineering institutions. On the forthcoming retirement of Lord Weir, the directors of G. and J. Weir, Ltd., propose to appoint the Hon. J. Kenneth Weir, the present managing director, to the chairmanship.

Water Pollution Research in 1954

THE D.S.I.R.'s annual report on water pollution research during 1954 includes an account of the new laboratory at Stevenage, which was occupied during the year. The survey of the Thames Estuary, which the Water Pollution Research Laboratory has been carrying out, has proved to be of great complexity, it is stated, and during the past few years a large proportion of the staff of the Laboratory has been engaged in this work. The factors which determine the balance of oxygen in the estuary water have been closely studied, and it appears that two of the most important on the "credit" side are the flow of fresh water into the head of the estuary at Teddington, and the rate of absorption of oxygen from the air. It is estimated, for example, that the atmosphere contributes daily something like 1500 tons of oxygen to the water in the estuary. This oxygen is used in oxidising polluting matter discharged to the estuary, and a method of calculating the rate at which this occurs is described. Field investigations and experimental work have now been brought to an end and the lengthy calculations necessary before final conclusions can be drawn are in progress. The increasing use of synthetic detergents is being investigated at the Laboratory, but work on the effect of these materials on sewage treatment has so far been inconclusive. The effect of pollution on fish was also studied and the Laboratory is attempting to correlate the results of its observations in the River Colne, at the effluent channel of the Maple Lodge sewage works, with chemical conditions in the channel. Examination of the quality of surface run-off water from a large modern housing estate at Oxhey, Hertfordshire, showed that the water had a high content of suspended solid matter but that otherwise it was not very polluting in character. The results of experiments with large and small percolating filters at Minworth, Birmingham, and with small filters at Finham, Coventry, confirmed that the length of the period between applications of doses of sewage, which is, of course, determined by the rate of travel of the distributor, has a considerable effect on the efficiency of a filter. It was noted in the last report that some cyanides could be destroyed by biological action in a percolating filter; the organism responsible has now been isolated and has been found to be an actinomycete, and a practicable biological method for removing cyanide was tried out. The results obtained in a pilot plant in which partially neutralised black liquor from kiering of cotton was digested anaerobically showed that this would be a possible method for pretreatment of the liquor before discharge to a public sewer.

Materials Handling

THE British Productivity Council has just published one of its "action pamphlets" on the subject of the handling of materials. The object of these pamphlets is to disseminate as widely as possible a knowledge of the techniques that make for higher productivity. They provide concise statements of the principles involved, the method of application and the benefits to be derived. In dealing with the benefits a manufacturing concern can derive from good materials handling, it is pointed out that estimates have shown that from one-third to one-sixth of the annual wage bill of manufacturing industries can be attributed to handling. Calculations have shown that the provision of an uninterrupted flow of materials to and from each worker would, on the average, raise productivity by at least 15 per cent. Sections of the booklet deal with the principles of good materials handling and the methods of application before going on to describe some typical equipments. Particular stress is laid on the desirability of studying any job and finding means of reducing handling to a minimum before consideration is given to ways in which it can be mechanised. It is pointed out that it is a fallacy to think that economic and efficient materials handling is important only to large concerns, as bad handling methods are wasteful in any factory irrespective of its size or production.

London Engineering Firm's Centenary

THE London firm of George Wailes and Co., Ltd., is now celebrating the centenary of its formation. It was established by Mr. George Wailes, who soon after completing his apprenticeship with Ardill and Pickard, of Leeds, acquired two engineering businesses, one of them being the Phoenix Ironworks at Stroud, and the other the machine shop and foundry of Charles Rich, at Palace Row, New Road, London. In both places Mr. Wailes traded under the title of George Wailes and Co., and in the early days of the business he used to spend three days a week at the London works. George Wailes came to London to live in 1856, and about that time disposed of the Stroud establishment. In 1881, George's eldest son, Herbert Wailes, joined the firm, having served an apprenticeship with Peter Brotherhood, Ltd. He left in 1904 to go to Canada, where he achieved distinction as a marine biologist. Prior to that, in 1889, the younger son of the founder, Mr. Reginald Percy Wailes, began an apprenticeship with the firm, becoming subsequently assistant foreman, and outside manager and, finally, a partner. In 1906 Mr. George Wailes retired, but Mr. R. P. Wailes decided to continue the business. He hired temporary premises in Euston Buildings, retained the name of the firm, and later moved to the works which the firm now occupies at 386, Euston Road. For some years Mr. Carl Skinner, of the S.U. Carburettor Company, was a partner in the concern. In 1924, Mr. R. P. Wailes was joined by his elder son, Mr. Rex Wailes, who had been trained in the works of Robey and Co., Ltd. The firm of George Wailes and Co., Ltd., became a limited liability company in 1929, and on the death of Mr. R. P. Wailes in 1952, Mr. Rex Wailes succeeded to his present position of chairman and managing director.

Social Research in Industry

DURING this week-end a meeting is to be held at York of scientists who are engaged on social research in industry. The meeting has been arranged jointly by the Acton Society Trust and the York Civic Trust. All the scientists who will be present are engaged in studies of the behaviour of individuals or organisations in industry, and are representative of nine European countries. They are drawn from the sciences of sociology, psychology and anthropology. The purpose of the gathering is to enable research workers in different countries, studying similar problems, to get to know each other and to exchange experience in methods of applying their discipline to industrial problems. A similar gathering, on that occasion of British scientists only, was held in York in October, 1953, and the interest aroused in other countries has encouraged the Acton Society Trust to organise the present meeting. The discussions will be both on actual pieces of research carried out and on problems of interest to research workers everywhere, such as achieving co-operation in industry and getting the results of research translated into action.

Discharge of Gas from Cylinder to Atmosphere

By R. S. BENSON, M.Sc. (Eng.), A.M.I.Mech.E., A.M.I.Mar.E.*

No. I

The discharge of gas from cylinder to atmosphere is analysed by the method of characteristics. It is shown that for isentropic flow a depression can occur in the cylinder under all conditions immediately at the end of the discharge, the magnitude depending on the ratio of the port area to cylinder cross-sectional area. The duration of the depression depends on the initial pressure and temperature, cylinder length and ratio of port area to cylinder cross-sectional area. Excepting in the case of certain low release pressures the magnitude of the depression is independent of the release pressure. The analysis also indicates that the mode of the discharge is different for gradual port opening compared with sudden port opening, the magnitude of the depression depending on the port area at the end of the discharge. By an approximate method the possibility of a depression occurring in two-stroke-cycle engines is examined. Curves are produced showing the port area at the end of the discharge as a function of cylinder stroke-bore ratio, port width, release pressure and temperature, cylinder length and engine speed. These curves confirm that a depression can be obtained more readily with through-scavenged engines, with a high stroke-bore ratio, earlier exhaust port opening and with a high engine number (engine speed × cylinder length).

IN recent years the study of the discharge phenomena from a cylinder of two-stroke-cycle engines has been given added impetus by the development of engines operating on the Kadenacy system. At the time of the early controversies on the nature of the discharge processes associated with the Kadenacy system, in particular the cause of the depression in the cylinder after exhaust blow-down, the phenomenon was mainly associated with engines operating above 800 r.p.m. In some recent investigations[1] the same type of phenomenon was observed on large slow-speed marine diesel engines with large-diameter exhaust pipes (cross-sectional area about 1·7 times cylinder area) and long pipe runs up to 220ft. Any suggestion of negative reflection effects at the pipe end could be discounted; it therefore appeared that engine speed alone was not the important criterion. Although at the time the subject was not pursued further except to compare the observed depression with that calculated by Giffen's[2] method a recent theoretical investigation in connection with the formulation of experimental data on exhaust port design and other problems involving the method of characteristics revealed interesting information on the discharge phenomena of a cylinder exhausting to atmosphere. In particular the analysis cleared up the doubtful conclusions of the earlier theories[2, 3] on the nature of the fortuitous relationships between the magnitude of the depression and the release pressure. By extending the theory to cover the whole range of port areas likely to be obtained in practice, it was possible to establish the criteria for engine port design to obtain the depression effects referred to by Kadenacy for discharge to atmosphere or into the large exhaust pipes of the type normally used in marine practice.

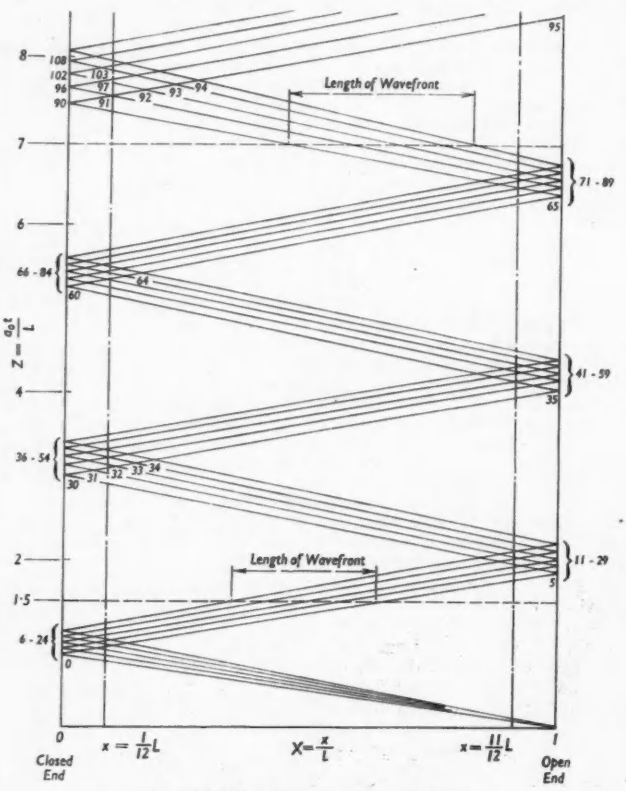


Fig. 1—Position diagram, sudden discharge

(1) Fundamental Theory

The basic equations for one dimensional fluid flow in a pipe of constant cross section are[4]:

Continuity:

$$\rho u_x + u\rho_x + \rho_t = 0 \quad . \quad . \quad . \quad . \quad (1)$$

Euler:

$$\rho u_t + \rho u_x u + p_x = 0 \quad . \quad . \quad . \quad . \quad (2)$$

where the suffix indicates the partial derivatives with respect to x or t.

ρ = density.

u = velocity.

p = pressure.

These two equations can be combined by the use of the velocity potential

$$\phi_x = \frac{\partial \phi}{\partial x} = u$$

into the form

$$(a^2 - \phi_x^2)\phi_{xx} - 2\phi_x\phi_{xt} - \phi_{tt} = 0 \quad . \quad . \quad (3)$$

where ϕ_t is defined by the following expression

$$a^2 = a_0^2 - \frac{\gamma - 1}{2}\phi_x^2 - (\gamma - 1)\phi_t \quad . \quad . \quad (4)$$

for isentropic flow.

a = local instantaneous velocity of sound.

a_0 = velocity of sound at $u = 0$.

γ = ratio of specific heats.

$\phi_{xx}, \phi_{xt}, \phi_{tt}$ are $\frac{\partial^2\phi}{\partial x^2}$, $\frac{\partial^2\phi}{\partial x \partial t}$ and $\frac{\partial^2\phi}{\partial t^2}$ respectively.

Equation (3) is a quasilinear partial differential equation of the type

$$A\phi_{xx} + 2B\phi_{xt} + C\phi_{tt} = D \quad . \quad . \quad . \quad (5)$$

where coefficients A, B, C and D may contain functions of x, t, ϕ_x, ϕ_t.

No general solution of the above equation in the form $\phi = \phi(x, t)$ is at present known; partial solution of (5) to yield values of ϕ_x and ϕ_t, however, can be obtained and these enable the physical properties of the fluid at a point (x, t) to be evaluated.[4]

Each point (x, t) on the integral surface $\phi = \phi(x, t)$ has an associated value of ϕ_x, ϕ_t; small displacements in x, t will cause small changes in ϕ_x, ϕ_t represented by the expressions

$$d\phi_x = \phi_{xx}dx + \phi_{tx}dt \quad . \quad . \quad . \quad . \quad (6)$$

$$d\phi_t = \phi_{xt}dx + \phi_{tt}dt \quad . \quad . \quad . \quad . \quad (7)$$

$$\phi_{xt} = \phi_{tx}$$

since the fluid properties in the field are continuous.

Lines on the integral surface $\phi = \phi(x, t)$ can be projected on the x, t plane; associated with each point x, t there will be a corresponding value of ϕ_x and ϕ_t and a new series of lines can be replotted on what may be called a ϕ_x, ϕ_t plane. If the derivatives of ϕ_x and ϕ_t, i.e. ϕ_{xx}, ϕ_{tt}, ϕ_{xt}, are indeterminate along the projections on planes x, t and ϕ_x, ϕ_t it is possible to establish a relationship between the slopes of the projected lines which on evaluation release the physical properties required. Such lines along which the partial derivatives are indeterminate are called "characteristics" and the projections on the x–t, or ϕ_x–ϕ_t or any other plane are called "characteristic diagrams."

Equations (3)—or (5)—(6) and (7) can be regrouped in determinant form to obtain indeterminate solutions of ϕ_{xx}, ϕ_{xt}, ϕ_{tt}. For example for ϕ_{xt} we have

$$\phi_{xt} = -\frac{\begin{vmatrix} a^2 - \phi_x^2 & 0 & -1 \\ dx & d\phi_x & 0 \\ 0 & d\phi_t & dt \end{vmatrix}}{\begin{vmatrix} a^2 - \phi_x^2 & -2\phi_x & -1 \\ dx & dt & 0 \\ 0 & dx & dt \end{vmatrix}} \quad . \quad (8)$$

For this to be indeterminate both numerator and denominator must be zero; two equations

* Lecturer in Mechanical Engineering, University of Liverpool.

[1] "The Flow of Gases in Large Two-Stroke-Cycle Diesel Engines," Benson, R. C. J. S. Dissertation for M.Sc. (Eng.), London University, 1954.

[2] "Rapid Discharge of a Gas from Vessel into Atmosphere," Giffen, E., *Engineering*, Vol. 150 (1940), page 134.

[3] "Wave Action Following Sudden Release of Compressed Gas from a Cylinder," Bannister, F. K., and Mucklow, G. F., *Proc. I.Mech.E.*, Vol. 159 (1948), page 269.

[4] "Non-Stationary Problems of Gas Dynamics (Pressure Waves of Large Amplitude)," R. Sauer (Ministry of Supply Theoretical Research Translation 1/47).

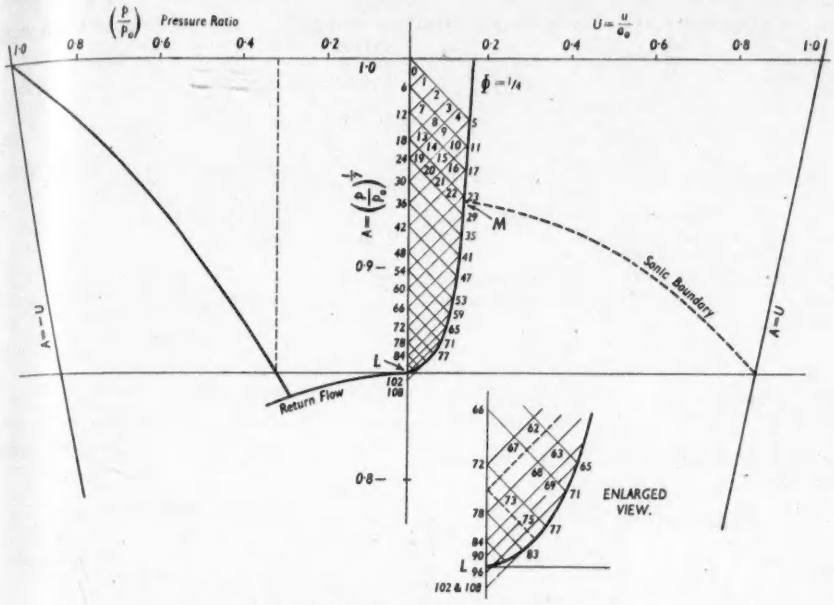


Fig. 2—State diagram, sudden discharge

thus formed will give the slope of the characteristics in the x–t, ϕ_x–ϕ_t planes.

The equation represented by the denominator is called mathematically the direction condition and is

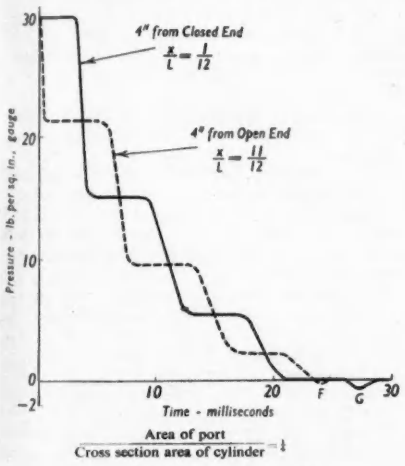
$$\frac{dt}{dx}=\frac{1}{\phi_x \mp a}$$

or

$$\frac{dx}{dt}=u \mp a, \text{ since } \phi_x=u \quad . \quad . \quad . \quad (9)$$

A characteristic diagram in the x–t plane is called the " position " diagram (Fig. 1).

The equation represented by the numerator



Area of port / Cross section area of cylinder = ¼

Characteristic diagrams Figs. 1 and 2

Fig. 3—Calculated indicator diagrams for vessel 4ft long

is called mathematically the compatibility condition and is

$$\frac{d\phi_t}{d\phi_x}=-(\phi_x \pm a) \quad . \quad . \quad . \quad (10)$$

This can be converted directly into the physical properties velocity u and local speed of sound a by means of equation (4), and the plane is changed into the a–u plane. Equation (10) becomes

$$\frac{da}{du}=\pm\left(\frac{\gamma-1}{2}\right) \quad . \quad . \quad . \quad . \quad (11)$$

where $\frac{da}{du}$ defines the slope of the characteristics in this plane. A characteristic diagram in the a–u plane is called a " state " diagram (Fig. 2).

In developing equations (9) and (11) the mathematical properties of the basic flow equations have only been used, and it will be seen that on integrating these equations the velocity of the fluid (u) and the parameter of state (a) [since the local velocity of sound is a function of temperature] can be obtained at each point, provided the constant of integration is known. The latter is obtained from the boundary conditions.

For a constant value of γ integration of equation (11) yields

$$a-a_0=\mp\left(\frac{\gamma-1}{2}\right)[u-u_0] \quad . \quad . \quad . \quad . \quad . \quad (12)$$

and if the fluid is initially at rest $u_0=0$ and

$$u=\mp\left(\frac{2}{\gamma-1}\right)[a-a_0]$$

or

$$u=\mp\left(\frac{2}{\gamma-1}\right)a_0\left[\left(\frac{p}{p_0}\right)^{\frac{\gamma-1}{2\gamma}}-1\right] \quad . \quad . \quad (13)$$

since

$$\frac{a}{a_0}=\left(\frac{p}{p_0}\right)^{\frac{\gamma-1}{2\gamma}} \text{ for isentropic flow} \quad . \quad (14)$$

where p_0=pressure at rest.

Equation (13) is the equation of the finite pressure wave.[2, 3]

In order to apply the graphical solution of equations (1) and (2) by the method of characteristics it is necessary to establish the boundary conditions from which the characteristic net can be plotted in both state and position diagrams.

(2) Boundary Conditions for a Cylinder with a Port at One End[5]

At the closed end the boundary conditions on the state diagram are along $u=0$, since the velocity at the closed end is zero.

At the open end the boundary conditions are obtained by equating the velocity and pressure conditions immediately before the ports (suffix 1) with the conditions in the *vena contracta* of the convergent stream (suffix 2). For no losses between the cylinder and *vena contracta* the equation of conservation of energy is

$$a_1^2+\frac{\gamma-1}{2}u_1^2=a_2^2+\frac{\gamma-1}{2}u_2^2 \quad . \quad . \quad (15)$$

and continuity

$$u_1\rho_1=\Phi u_2\rho_2 \quad . \quad . \quad . \quad . \quad (16)$$

where

$$\Phi=\frac{\text{effective area of stream at } \textit{vena contracta}}{\text{cylinder cross-sectional area}}.$$

[5] " The Application of a Graphic Method to Some Dynamic Problems in Gases," Haller, P., *Sulzer Technical Review*, 1945, No. 1, page 6.

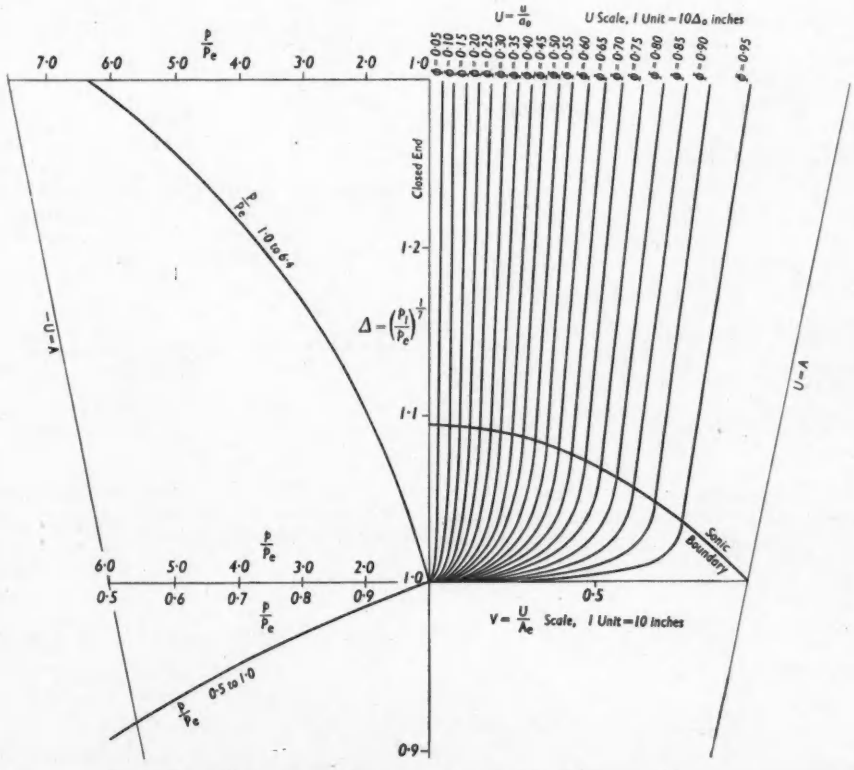


Fig. 4—Generalised chart of boundary curves for flow from a cylinder

The density and pressure are connected as before by the equation of state

$$\frac{p}{\rho^{\gamma}}=c \quad . \quad . \quad . \quad . \quad . \quad (17)$$

Using the non-dimensional parameters suggested by Haller[5]

dimensionless velocity of sound $A=\frac{a}{a_0}$;

dimensionless particle velocity $U=\frac{u}{a_0}$;

dimensionless time ... ... $Z=\frac{a_0 t}{L}$;

and dimensionless length ... $X=\frac{x}{L}$;

where L is the length of the cylinder.

The characteristic equations become

$$\frac{dX}{dZ}=U\pm A \quad . \quad . \quad . \quad . \quad (18)$$

$$\frac{dA}{dU}=\pm\frac{\gamma-1}{2} \quad . \quad . \quad . \quad . \quad (19)$$

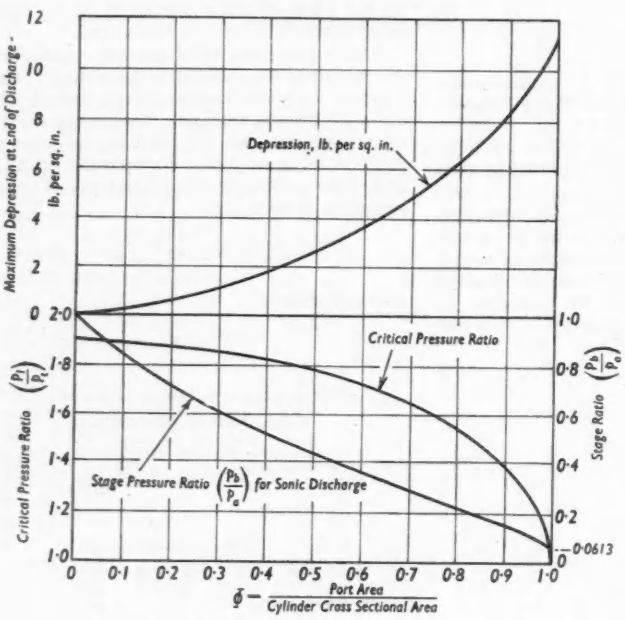

Maximum Depression at End of Discharge - lb. per sq. in.
Depression, lb. per sq. in.
Critical Pressure Ratio
Stage Pressure Ratio $\left(\frac{p_b}{p_e}\right)$ for Sonic Discharge
Critical Pressure Ratio $\left(\frac{p_1}{p_e}\right)$
Stage Ratio $\left(\frac{p_b}{p_e}\right)$
0·0613
$\phi=\frac{\text{Port Area}}{\text{Cylinder Cross Sectional Area}}$

Fig. 5

equation (15) becomes

$$A_1^2+\frac{\gamma-1}{2}U_1^2=A_2^2+\frac{\gamma-1}{2}U_2^2 \quad . \quad (20)$$

equation (16) with (17) becomes

$$U_1 A_1^{\frac{2}{\gamma-1}}=\Phi A_2^{\frac{2}{\gamma-1}}U_2 \quad . \quad . \quad (21)$$

and by combining (20) and (21)

$$U_1^2=\frac{\frac{2}{\gamma-1}[A_1^2-A_2^2]}{\left[\frac{1}{\Phi^2}\left(\frac{A_1}{A_2}\right)^{\frac{4}{\gamma-1}}-1\right]} \quad . \quad . \quad (22)$$

The maximum velocity at the *vena contracta* will in the usual manner be the local velocity of sound, i.e. $U_2=A_2$, whence equation (21) becomes

$$\frac{U_1}{A_2}=\Phi\left(\frac{A_2}{A_1}\right)^{\frac{2}{\gamma-1}} \quad . \quad . \quad . \quad . \quad (23)$$

and (20)

$$\frac{2}{\gamma-1}\left(\frac{A_1}{A_2}\right)^2+\left(\frac{U_1}{A_2}\right)^2=\frac{\gamma+1}{\gamma-1} \quad . \quad . \quad (24)$$

Substituting $\gamma=1{\cdot}4$ and combining equation (23) and equation (24) we have the expression:

$$\Phi^2=\left(\frac{A_1}{A_2}\right)^{10}\left(6-5\left(\frac{A_1}{A_2}\right)^2\right) \quad . \quad . \quad (25)$$

where

$$\frac{A_1}{A_2}=\left(\frac{p_1}{p_t}\right)^{1/7}=\left(\frac{A_1}{A_2}\right)_{cr} ;$$

the critical pressure ratio $\frac{p_1}{p_t}$ being obtained from (25), this will have a different value for each value of Φ (Fig. 5). If the pressure in the cylinder is greater than the critical pressure then flow through the orifice is under sonic conditions and the boundary curve is now given by

$$\frac{U_1}{A_1}=\Phi\left(\frac{A_2}{A_1}\right)_{cr}^{\frac{\gamma+1}{\gamma-1}} \quad . \quad . \quad (26)$$

Since $\left(\frac{A_2}{A_1}\right)_{cr}$ is a constant U_1 and A_1 are connected linearly ; the boundary curve is a straight line passing through the point $U_1=0$, $A_1=0$ with slope $\Phi\left(\frac{A_2}{A_1}\right)_{cr}^6$.

The boundary curve for a given value of Φ can be calculated from equations (22) and (26) or constructed graphically by a method suggested by Haller.[5] The boundary curve for $\Phi=\frac{1}{4}$ is shown in Fig. 2 for an initial cylinder pressure $p_0=30$ lb/in² gauge and exhaust pressure $p_2=p_e=0$ lb/in² gauge. At the point $A=A_1=A_2=A_e$ the pressure in the cylinder equals the exhaust pressure and the particle velocity U_1 at the ports is zero.

Since the non-dimensional parameter $A=\left(\frac{p}{p_0}\right)^{1/7}$ is a function of the initial pressure p_0, the boundary curves must be replotted for each value of p_0. Jenny[6] has produced a series of boundary curves for flow through a nozzle which can be adapted for this purpose. To avoid redrawing the boundary curves for each example a generalised boundary chart (Fig. 4) may be used. In this chart, the parameter of state is

$$\Delta=\frac{A_1}{A_e}=\frac{a_1}{a_e}=\left(\frac{p_1}{p_e}\right)^{1/7}$$

where A_e corresponds to the condition of pressure equalisation across the ports, the parameter of velocity is

$$V=\frac{U_1}{A_e}=\frac{u_1}{a_e}.$$

By suitable selection of scales the boundary chart can be converted directly into a state diagram with 45 deg. characteristics.[5]

$$\Delta=1 \text{ when } \left(\frac{p_1}{p_e}\right)^{1/7}=1$$

i.e. when $p_1=p_e$ the pressure at the end of the expansion

$$\Delta_0=\left(\frac{p_0}{p_e}\right)^{1/7}=\frac{a_0}{a_e}=\frac{A_0}{A_e}$$

corresponds to the initial conditions in the cylinder.

For subsonic flow $\frac{A_2}{A_e}=1$ and equation (22) is

$$V^2=\frac{5[\Delta^2-1]}{\frac{\Delta^{10}}{\Phi^2}-1} \quad . \quad . \quad . \quad . \quad (27)$$

for sonic conditions in the port equation (24) becomes

$$V_c^2=6-5\Delta_c^2 \quad . \quad . \quad . \quad . \quad (28)$$

equation (26) becomes

$$V=\Phi(\Delta_c)^{-6}\,.\,\Delta \quad . \quad . \quad . \quad (29)$$

where V_c and Δ_c are the values of $\frac{u_1}{a_e}$ and $\frac{a_1}{a_e}$ at the critical pressure. Equations (27), (28), (29) are plotted in Fig. 4. The generalised boundary chart can be converted directly into the usual non-dimensional state diagram by multiplying the scales of Δ and V by Δ_0 ; $\Delta=\Delta_0$ $V=0$ will then be the point $A=1$, $U=0$ for the state diagram. Fig. 4 is drawn for 45 deg. characteristics.

(*To be continued*)

[6] "Berechnung und Modellversuche über Druckenwellen Grossen Amplituden in Auspuff-Leitungen," Jenny, E. (Doctors Thesis Z.T.H.S., 1949).

Marine Machinery of the Immediate Future

A PAPER entitled "Marine Machinery of the Immediate Future from the Shipowner's Point of View," was read before the Institute of Marine Engineers on Tuesday, April 12th, by J. E. Church.

The paper begins by calling attention to the present very high cost of building ships. As a way out of the difficulty it is suggested that it may be necessary to consider cheaper, light weight, medium speed machinery which, besides allowing more cargo to be carried by virtue of the saving in weight and engine-room space, may result in reduced running costs in spite of possible heavier repair costs because of higher output ratings. It is suggested that slightly higher fuel consumption may be acceptable if it results in reduced depreciation which will follow if new ships can be built more cheaply.

A number of proposed machinery types comprising diesel, diesel and steam combinations, and, finally, a gas-steam turbine combination, are put forward, which show considerable advantages over present orthodox types and it is shown that by adopting these, not only would first cost be very much less, but daily running costs would be little if any higher and in one instance even lower.

The point is also made that these proposals, by splitting the prime mover into more than one engine per screw, reduce the risk to which the present-day large and very valuable single-screw ship is exposed in the event of major engine breakdown, such that complete immobilisation would be practically impossible.

A factor behind the consideration of combined steam and diesel machinery is the desire to utilise very heavy fuel for the steam side of the plant and distillate fuel for the diesels, rather than a blend of the two, now mistakenly termed "heavy fuel" for motorships, in order to avoid the distressing troubles and difficulties being experienced by using such inferior fuels in diesel engines.

The gas-steam turbine proposal, it is put forward, has many advantages and would enable the shipowner to send gas turbines to sea without any risk to the ship very much sooner than would otherwise be the case, as the problems of reversing are at once overcome, and better efficiencies are possible without the need of any heat exchangers or complicated, multiple turbine arrangements.

The paper concludes by suggesting that such smaller and lighter engines now render it possible to consider moving the engine-room aft a little, giving a further increase in cargo cubic capacity and enabling the large middle section of the ship to be better used for cargo, besides reducing the maximum bending moment.

Applied Mechanics

No. III—(*Concluded from page 515, April 15th*)

At a meeting of the Institution of Mechanical Engineers, which began after lunch on April 1st and continued into the evening, a number of papers were read and discussed. The meeting was organised by the Applied Mechanics Group and we here print summaries of the papers and abstracts from the discussions.

THE remaining papers presented at the meeting of the Institution of Mechanical Engineers on April 1st were:

AN ELECTROLYTIC TANK INVESTIGATION INTO STEPPED THRUST-BEARINGS

By C. F. KETTLEBOROUGH, B.Eng., Ph.D.*

Many years ago the very unsatisfactory bulky and expensive multi-collar thrust-bearing was replaced by the very compact Michell tilting-pad thrust-bearing, which has given very satisfactory service. Of recent years interest has been focused on simpler types of non-tilting thrust-bearings such as parallel-surface bearings and bearings with a machined taper. There is a general desire for a satisfactory, cheap, simple thrust-bearing. An investigation into stepped thrust-bearings has been carried out with an electrolytic tank, and results indicate that the load capacity is greater than for the tilting-pad bearing. The friction is increased but not in the same proportion as the load capacity. By a suitable choice of the operating conditions it is possible to design a stepped-pad thrust-bearing which operates over a wide range of loads with a greater film thickness and a lower coefficient of friction than a tilting-pad thrust-bearing. Owing to the decrease in friction and the simple and cheap construction, there appears no outstanding reason why this new bearing should not supersede the conventional tilting-pad thrust-bearing.

JOURNAL BEARING PERFORMANCE UNDER SINUSOIDALLY ALTERNATING AND FLUCTUATING LOADS

By G. S. A. SHAWKI, B.Eng., Ph.D.† and P. FREEMAN, B.Eng.‡

A testing machine has been designed and developed to investigate the performance of a complete journal bearing under a vertical cyclic load of the form $P = P_0 + P_1 \sin(\omega_1 t) + P_n \sin(n\omega_1 t + \psi)$. This paper presents the results of the experimental study of the bearing performance for the case where $P_n = 0$ and for values of P_1/P_0 between infinity and zero inclusive. Test results show that the ratio of the rate of load application to that of journal rotation (ω_1/ω) is a prime factor in the bearing behaviour. Values of this ratio slightly less than 0·5 give rise to critical changes in the bearing performance, of a character mainly dependent on the ratio of P_1 to P_0. The results do not, in general, confirm the theory put forward by Swift; they do, however, indicate closer agreement with some recent theoretical studies. Further work on the subject is proceeding.

SOME FURTHER TESTS ON HIGH-SPEED BALL-BEARINGS

By F. T. BARWELL, Wh.Sc., Ph.D., B.Sc.(Eng.),§ and M. J. HUGHES, B.Sc.(Eng.)‖

Friction torque and natural running temperature of "light"-type and "extra-light"-type bearings of bore 5in have been measured at speeds ranging from 5000 to 11,000 r.p.m. Loads up to 2400 lb were applied at varying incidence of radial to thrust load. Lubrication was by liquid jet at the rate of 6 pints per minute. It is concluded that a large proportion of the friction measured under the conditions of lubricant supply adopted in the experiments is attributable to viscous friction in the lubricant. An analysis of the friction torque based on the work of Poritsky, Hewlett and Coleman (1947) for varying angles of application of load shows no correlation with the experimental results obtained. Estimates of hysteresis loss based on the work of Tabor (1952, 1954) indicate that this factor represents a comparatively small proportion of the total frictional loss of bearings of this type.

DISCUSSION

Dr. A. Cameron: I should like to ask Mr. Freeman if it is possible, by putting strain gauges on the loading arm, to obtain the values of damping, as that would settle whether the source of damping referred to in the paper by Mr. Yates is due to the non-linearity of the oil film. I should have thought that that might have been obtained by a fairly simple extension of the authors' apparatus. Have the authors looked into the question of temperature distribution across the oil film? Normally, in Reynolds' treatment he assumes that the temperature gradient, and hence the viscosity, is constant. Therefore, you can differentiate the first equation provided that you assume constant viscosity.

I now turn to Dr. Barwell's paper.

Has Dr. Barwell correlated the stresses which were causing pitting with the loads and the ultimate tensile strength of the steel? In other words, do the elastic stresses cause pitting to anything like the extent that you would expect from the ultimate tensile stress? He says that the assumption of an oil film is not justified. I should like to know on what he bases that statement. In a very small amount of work that I have done on ball bearings trying to use them as lip rings, I have found that there is always a fairly considerable electrical resistance, and I should have thought that the published method of using the potential drop would give an indication that there definitely is an oil film of about a few tenths of a thousandth. I also wonder what proportion of the total measured friction the hydrodynamic friction would be, assuming a few tenths of a thousandth of oil film between the balls and the race.

Dr. F. T. Barwell: I think Dr. Kettleborough's conclusions are rather sweeping. We must remember that these are calculations which do not take into account the variation of viscosity with temperature, and I do not think that the case has been made out for rather strong words like "There appears to be no major reason why this simple bearing should not supersede more expensive thrust bearings." An advantage of the Michell bearing is that it will tolerate a little running in the reverse direction, but it does not appear that the stepped bearing could do that.

Mr. J. S. Webber: A point of particular importance which emerges from the paper by Barwell and Hughes is that the criteria which are applicable to smaller ball bearings may not be extended to cover sizes of 5in bore and over. Further, it would seem that this is basically due to the fact that in the larger sizes of bearing the rate of self-heating is so high that relatively large quantities of lubricant have to be used, more in order to cool the bearing than to act as a lubricant, as the demands of this type of bearing for lubricant have been shown to be not excessive. The shearing and churning of this mass of oil gives rise to friction torques of sufficient magnitude to mask friction arising from other effects. Thus, the hysteresis factor postulated by Tabor and the "micro-slip" which occurs at the areas of contact of the balls become of small importance, and the known load-friction effect also becomes a secondary factor. It has been shown by Fogg and Webber (1955) that for smaller bearings lubricated by small feeds of oil mist the heat generation of ball bearings is a maximum when ϕ lies between 30 deg. and 70 deg., and this has been attributed to the complex slipping motion of the balls. It is interesting to note that in spite of large oil feeds this factor is still of major importance, as is evidenced by Fig. 4. It is disappointing, then, that the analysis of friction losses made by Poritsky, Hewlett and Coleman fails to give better agreement with experiment, and presumably here a more comprehensive analysis is awaited.

Secondly, it would seem that although the authors' conclusion concerning the relative equality in performance of light and extra-light type bearings cannot be disputed, the merits of a small number of balls as against a large number of balls is not disproved thereby. Reference to Fig. 1 in the paper shows that the twelve-ball bearing has larger balls than the nineteen-ball bearing. The size of the former will give rise to large areas of contact between ball and race, and this would make slipping losses under combined loading conditions severe, thus offsetting the advantage gained by reduction in the number of balls. A more rigorous check on this particular point would have been to reduce the number of balls in a given bearing. Indeed, this might have desirable secondary effects in that if the friction torque and self-heating of the bearing were reduced thereby, it might be possible in practice to reduce the amount of oil acting as coolant and so reduce churning losses also.

Finally, it is interesting to note the authors' conclusion about the insignificant effect produced by varying the contact angle of the bearing from 18¼ deg. to 22½ deg. The formula for contact angle indicates that deliberate variation of the contact angle in a given bearing may be brought about by altering either diametral clearance or by altering track curvature. In terms of heat generation in the bearing under combined load, however, the second factor has been shown in the earlier paper to be of much greater significance than the first. In the present paper, the track curvature factor was the same for all the bearings, that is 5 per cent, and the constancy of this factor may explain the result quoted.

Mr. W. J. Davies: Temperature rise and friction torque measurements were considered by the authors as the main criteria of bearing performance. However, if these criteria are persisted in there is quite a danger of conclusions being drawn which mislead as to the best bearing designs for achieving adequate overall mechanical reliability, including freedom from surface fatigue of tracks and rolling element. I consider that provided steps are taken to keep down temperature rise—for instance, by increased lubrication, or, alternatively, by more cooling air—a design and operating condition giving relatively high friction torque is not necessarily to be avoided. In fact, experience on aircraft gas turbine applications has indicated that the most reliable designs are not those which the authors find give least friction. Indeed, in aircraft applications I think that close conformity, larger diametric clearance and high contact angle have been definitely established as giving a better capacity and fatigue life. While friction will be higher, this is not generally of real significance, provided that its temperature effects are adequately controlled. Thus, in general, the temperature and friction criterion of performance adopted by the authors is an unreal one, though its use has yielded much interesting data when considering the slide-roll

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conditions that exist inside the bearing.

I should like to make a few remarks about changes to internal geometry due to load and speed. I found it very surprising, incidentally, that in neither papers was there any mention of a most important item affecting the performance of high-speed ball-bearings, namely ball centrifugal force. Also, performance under thrust load was considered in terms of the contact angle obtaining only under light thrust load at very low speed. I think that the authors could well have considered the very considerable changes to the contact angle which come about due to ball and track deformations under applied load and due to disparities in magnitude and direction of ball loads on inner and outer track due to ball centrifugal force.

I now turn to reasons for temperature instability of high-speed ball-bearings under thrust. It will be noted that the internal sliding of a ball-bearing under thrust load will be much worse at high speed and light load but, of course, the friction forces, overcome when slipping, are also light and the energy dissipated is not very high. At the other extreme, namely heavy thrust and low speed, friction forces are large but sliding low and, again, power dissipated is not very high. However, between low thrust, high-speed and high thrust, medium-speed conditions there is an important region where friction rises very sharply with increase of duty, either of speed or of load. I think that is the real reason for the rise in temperature of high-speed ball-bearings with fairly large balls. I have not worked out accurately the ball centrifugal force for the large bearing mentioned in the paper by Dr. Barwell and Mr. Hughes, but, checking it over roughly, it would seem that the centrifugal force on one ball is about 300 lb.

Mr. A. E. Burke: I should like to make a comment on the paper by Shawki and Freeman, particularly with reference to engine bearing design.

One of the complicating features of journal bearing design is that bearings can fail in several different ways. For instance, a bearing which is under steady load uniform in direction may fail because the minimum film thickness is reduced to something comparable with the surface finish, and the misalignment of the bearing, in which case you get wiping of the bearing material. On the other hand, a bearing under an oscillating or rotating load can fail because the stresses in the lining are fluctuating, and one gets a fatigue failure of the lining material, where cracking starts, and then the material breaks away. The loads on engine bearings generally are limited by the fatigue strength of the bearing material. The general present-day practice with engine bearing loads is such that the loads are very much greater than those considered in the paper. For instance, in terms of load in pounds per square inch maximum load, the test bearing was subjected to about 400 lb per square inch, whereas an engine bearing is commonly run at 2000 lb to 3000 lb per square inch.

In terms of load criterion, which is a more satisfactory comparison, the load criterion δ used by the authors, the maximum load criterion at which these bearings were tested was about twenty-two. Working out the corresponding load criterion for comparatively heavily loaded diesel engine bearings, one gets a value of about 200; that is, ten times greater. We have actually run a white metal bearing at a load of 8000 lb per square inch, and the calculated δ for that case is 412; that is to say, some twenty times the maximum δ quoted in the paper. One cannot at the moment run bearings for any length of time at δ as high as that because one is limited by fatigue strength. The white metal bearing was run at 8000 lb per square inch, and that is some four times the load which will cause fatigue failure. Nevertheless, such bearings run for several hours at that load before fatigue failure commences, and there is no indication of difficulty, unless the film thickness should break down, with the bearing. That is not to say that it would not, nevertheless, be useful to obtain information from experiments such as these which would enable one to design bearings with increased minimum film thickness, because although that may not cause breakdown in engine bearings, it affects the rate of wear when one is lubricating a bearing with a lubricant which is not clean. However, even if such results are to be useful for that purpose, it would certainly seem necessary to extend the experiments to very much higher loads, to loads more comparable with the loads at present used in engineering practice.

Also, it is possible that with development of engine bearing materials and design features of bearings, the effect of design on minimum film thickness may become more important. If that is so, it is also necessary to have complementary work carried out to tell one what minimum film thickness is allowable. For instance, work was published in America dealing with the design of bearings for steady conditions. That could be of use to the designer in that it would enable him to predict minimum film thickness and conditions of speed. However, no information exists to tell him what minimum thickness is allowable from the design point of view which would allow one to run bearings without failure by wiping.

In the case of bearings under oscillating load, experimental work to establish the relationship between minimum film thickness and load conditions requires complementary work to establish what minimum film thickness is allowable before the two can be put together and be of use for design purposes.

Mr. R. A. K. Loxley: I was very interested indeed to read the paper by Dr. Kettleborough on the subject of the stepped thrust bearing. It seems to me that the solutions which he has suggested, and which he has, in fact, given by means of the electrolytic tank, will be of considerable use from the point of view of designing these sorts of thrust bearing, particularly as Dr. Kettleborough in his paper states that the solution to the problem of finding the load-carrying capacity and so forth for this sort of bearing can be obtained in about thirty minutes or perhaps a little longer.

In the firm with which I am associated we have over the last twelve-eighteen months carried out a short series of tests on stepped thrust bearings to estimate the load-carrying capacity and the performance. We carried out some earlier tests on some small thrust washers of about 2½in outside diameter and about ⅝in wide with eight parallel recesses spaced equally around the bearing, about two-thousandths of an inch deep at first. This gave a ratio of C_2/C_1 of recessed area to land of about half. We found that this failed at comparatively low loads at quite high temperatures, at about 75 deg. Cent. As a result of this, we carried out a series of tests with rings with a mean diameter of about 2½in and a width of ½in—that is, a width perpendicular to the direction of motion of the thrust collar—and we found some quite interesting results. We had in the bearing a number of sector-shaped pads approximately square, being ½in wide and ½in long in the direction of motion, and at the leading edge of every pad we put a cooling groove and placed the step about half-way along the bearing in the direction of rotation at the mean circumference of the bearing. We used recess depths from 1½–3 thousandths, and we loaded the bearing until we obtained failure. This approximately equal length of recess to land gives a ratio of C_2/C_1 of about unity. We originally used radial steps, and we used a white metal bearing surface running against a fine-grain steel rotating portion. We determined the failure criterion by the use of an electrical method, connecting a 1·5V cell through 15 ohm resistance across the running specimen and stationary thrust washer and connecting a cathode-ray oscillograph across the 15 ohm resistance. We were able to determine when failure took place by the degree of metal to metal contact that occurred between the bearing and the steel runner. With this type of bearing we were able to achieve loads before we estimated that failure had set in from 425 lb per square inch to as high as 900 lb per square inch on the bearing surface. We found that the design which had the greatest load-carrying capacity in this series of tests was that not with a non-radial groove but with a parallel recess.

As a further development in the investigation of the stepped bearings, we then proceeded to a type of bearing based on a design mentioned by Dr. Kettleborough in a paper that he published last year entitled "The Stepped Thrust Bearing—A Solution by Relaxation Methods." He suggested the use of a series of circular recesses as being easy to produce by pressing or machining in an annular thrust ring. This type of bearing will have the advantage that you could run it in the reverse direction because you have steps on both sides. We found this bearing, generally speaking, presented considerable difficulty in respect of carrying a load of the same order as that in the case of the straight stepped bearing, and the reason was that it over-heated fairly quickly. We came to the conclusion that the problem lay in keeping the bearings cool. We tried running cooling grooves across the surface of the stepped thrust washers, using a circular recess, but it was not entirely successful and did not improve the load-carrying capacity as much as we had hoped. We are still continuing tests on the various types of recesses and steps. We tried one thrust ring finally with circular recesses in which we supplied oil to the centre of each circular recess and ran cooling grooves underneath at the back of the washer concerned to try to dissipate the heat. We got that washer to fail at 775 lb per square inch.

In conclusion, I should like to say that testing is continuing on these bearings because it is my opinion that there is some considerable future for a bearing of this kind. It is very much cheaper and more easily manufactured than the tilting pad bearing. We are continuing with tests to obtain, we hope, measurements of film thickness and torque and various other important criteria of performance which we were not able to test during the earlier series.

Dr. H. W. Shaw: I am being forced to the opinion, and so is my company, that there is a gap in our more fundamental knowledge concerning the fatigue property of materials under the conditions in which they are used in ball bearings. We were recently faced with a number of failures on an angular contact thrust bearing. The material was the conventional 3½ per cent chrome. It was a 5in bearing running up to, I think, a maximum speed of 12,000 r.p.m., with a designed end thrust of about 7000 lb per square inch. It had probably

seventeen ¾in balls. We were faced with the problem of doing some development testing of bearings of that type and modifications to try to get rid of the trouble which was occurring in service. These tests were done on the kind of machine described in Fogg's paper, and we took the design from him at the end of the war. The first thing that we found, as has been mentioned by Dr. Barwell, was that we had a good deal of scatter in our results, but we had enough to get the general trend of the behaviour. Our usual failure was a failure of the inner track, a spalling failure which started with the conventional shear failure 15–20 thousandths below the surface and then a whole piece broke out. That was the general run of the experience about the surface; they were inner track failures. We were not very much bothered about it as it was inner track failure. We believed that it ran a little hotter. There was always the point that the inner track material was going through fatigue cycles rather more rapidly than the outer track. In parallel with carrying out experimental work, we instituted a design investigation. We considered the geometry of the ball under various elastic deformations arising at different speeds and different conditions of load. The first thing that emerged was quite encouraging. It explained our preponderance of inner track failures. At a certain load below the designed end load the shear stress on the inner track crossed over and exceeded the shear stress on the outer track. At the same time, we were able to get a measure of the skidding to which Mr. Davies referred. We carried out the investigation for the standard bearing of ¾in balls with a range of other balls in which the size of the balls was changed. Looking at that as a general picture of speed and load, it suggested that if we went to smaller balls, say ½in, we should pay the price of a higher shear stress, and I think the change was 20 per cent, but there was an improvement in the geometry and the difference between the inner and outer track contact angles was reduced. We ran bearings of that type under the same end load conditions as before and obtained superior results. We were taking up to 20 per cent more shear stress in the inner track, but the reduction in the skidding geometry represented an improvement of about 2 : 1. On the whole, the bearing life was improved considerably. That led us to the belief that the question of skidding gave rise to some surface friction effect which lowered the fatigue strength in this particular form of crushing loading. The step from that was to go back to our original loading and drop the end load from 9000 lb per square inch to 2500 lb per square inch. Under those conditions, bearings with bad geometry still failed at that. Therefore, we are led very strongly to the belief that in any problem of this kind if you are faced with skidding you are bound to accept a very considerable reduction in the crushing load which the material will take. We have not found very much literature on the point at the moment, but I put it to Dr. Barwell now that there may well be a subject there for him to investigate.

The authors replied briefly and the meeting ended.

PROTECTIVE SCREENS.—A protective screen is now being made by the Coleman-Wallwork Company, Ltd., Stotfold, Arlesey, Beds, for use in fettling shops and similar places where flying fragments are a source of danger to nearby operatives. These screens have a lower part of sheet steel with a close steel mesh upper section and stand 6ft 6in high. They are made in curved 11ft long units on angle iron frames and are self supporting. A number of units can be joined together or used individually in accordance with the size of the job being fettled, each screen being mounted on castors to facilitate its movement around the shop floor.

Bolted Connections in Aluminium Busbars

A REVIEW OF EXPERIENCE, WITH RECOMMENDATIONS

By J. C. BAILEY, B.Sc., F.I.M.*

The performance of bolted connections in busbars has frequently been criticised because of the tendency observed in some instances for high resistance to develop with the passage of time. This review of the data available indicates the essential factors in good jointing technique : and covers both laboratory studies and practical experience over thirty years. The first section summarises laboratory experiments, the second discusses observations and experience with actual busbar installations, and the final section gives recommendations regarding the essential requirements to be met for achieving bolted busbar joints of satisfactory low resistance and good stability.

EXPERIMENTAL WORK

THE classical work on busbar joints was carried out in 1922 by Melsom and Booth,[1] who established the relationship between pressure and contact resistance for both aluminium and copper busbar connections. They defined contact resistance for their purpose as the total resistance of a joint less the calculated resistance of the metal itself, corrected to allow for the streamline effect of the distorted path followed by the current in an overlap joint.

It is known from the extensive researches on contact resistance that have been done in connection with the surface preparation of aluminium for spot welding that this characteristic may be very variable and difficult to control. Contact resistance was found by Melsom and Booth to be a very inconsistent quality. In their tests, which were carried out on material of actual busbar size, surface preparation included machining and roughening, with and without a coating of petroleum jelly. Using these preparations, the contact resistance was plotted against the pressure both for aluminium and copper busbar systems : the bars were clamped together in a testing machine, using hydraulic pressure. Graphs were deduced for busbars of various sizes up to 6in wide and with various overlaps. Pressures over 2000 lb per square inch were necessary to give reasonably low contact resistance on aluminium bars, and a rather lower pressure for copper bars. Contact resistance fell rapidly with increasing contact pressure and was still falling even when pressures of 10,000 lb per square inch were reached.

Melsom and Booth, in their attempts to obtain consistent values for contact resistance, applied the pressure to their experimental joints a number of times before actually taking the measurements of contact resistance. This almost certainly accounts for the inconsistencies in contact resistance values recorded : it is now considered that when joints have been dismantled, they can only be satisfactorily remade by roughening the surfaces again so as to provide fresh points of contact. Nevertheless, their practical recommendations regarding size of overlap, surface roughening and the use of petroleum jelly were a valuable guide in practice, both for aluminium and for copper bars. Metzger[2] studied the influence of various surface preparations in bolted aluminium connections and his results, though not giving the same values for contact resistance as those found by Melsom and Booth, support the main findings. Metzger showed that small diameter bolts are not capable of developing substantial pressures between the bars, which was perhaps his distinctive contribution to the general body knowledge on the problem.

Koch[3] studied the behaviour of bolted aluminium joints in various corrosive media, including NaCl solutions, SO_2 atmospheres and industrial atmospheres. In each case there was an increase in contact resistance with time, but it was concluded that corrosive effects, even under severe conditions, were not excessive and immediate failure of the joints through developing high resistance need not be feared. Corrosion did not penetrate very far into the joints : lacquering of the assembly reduced the rate of increase in contact resistance with time, but did not prevent it altogether. Perhaps the chief conclusion to be drawn from this work is that a corrosive environment causes an increase in contact resistance with time, even when the joint surfaces have been coated with petroleum jelly. This would apply to aluminium/aluminium and to copper/copper joints. Bonwitt[4] carried out a comprehensive series of tests on bolted aluminium/copper connections. The bars were 1in by ¼in and in every case no surface preparation was done on the aluminium bars, but the copper bars were treated in a variety of ways. Corrosion tests and heat cycling tests were made over a period and in both of these tests the contact resistance increased considerably as a rule, but in a few instances heat cycling caused a decrease. Bonwitt concluded that the use of " Penetrox A " compound (petrolatum containing a high proportion of zinc dust) was beneficial. Zinc plating of the copper bars, cadmium plating and even tinning, were not found to be as satisfactory. Bonwitt's experiments indicate the need for appropriate preparation of the aluminium bars if undesirable rises in resistance are to be avoided, even though the initial joint resistance may be of a satisfactory low order.

Recent Test Work.—Some recent experiments[5] done on ¾in by ¼in aluminium bars for telephone work indicate the relationship between clamping pressure and contact resistance with various methods of surface preparation. Bar given no surface treatment, or abraded with No. 1 emery paper or with a file card had a relatively high resistance at the overlapping joint, even at 2000 lb per square inch pressure, but abrasion with No. 0 or No. 1 emery cloth, or with a double cut or rough file, gave joints of satisfactorily low contact resistance (joint efficiency slightly less than 1. Melsom and Booth define joint efficiency as the ratio—resistance of joint divided by resistance of an equal length of plain bar. Thus, a satisfactory joint is one with an efficiency less than 1), with a clamping pressure of 1500 lb to 1750 lb per square inch (Fig. 1). The bars in these tests were clamped under a hydraulic ram. It was concluded that cross filing (not draw filing) or treatment with emery cloth, in both cases under petroleum jelly, not removed before clamping up, would be satisfactory for both aluminium/aluminium bolted connections and aluminium/copper. For protection against humid conditions two coatings of petroleum jelly were recommended.

A parallel series of tests on copper busbars indicated that the same methods of surface treatment as above produced similar effects, and that filing of the copper bars is as desirable as for aluminium (Fig. 2). Also, the results of testing at various contact pressures were less reproducible than with aluminium, and the contact resistance tended to be higher : joint efficiency with overlap ten times the bar thickness was a little greater than 1/1.

The possible relaxation effects arising from the higher coefficient of linear expansion of aluminium (23×10^{-6} per deg. Cent.) compared with that of steel (12×10^{-6} per deg. Cent.) and of copper (17×10^{-6} per deg. Cent.) were considered, but felt to be unimportant in practice when operating at low current densities. An

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alloy steel of similar coefficient to that of aluminium has been developed (DTD.247), should it be considered desirable to take special steps in a particular case to eliminate all possibility of temperature effects. It was also concluded from this study that the size and material of the clamping bolts was important. The maximum compressive force exerted by a nut and bolt depends mainly upon the degree of tightening, the pitch of the threads, and the tensile strength of the bolt material. Bolts must therefore be selected of a size and strength that are capable of developing the required contact pressures, and thick washers or preferably a rigid clamping plate should be used to ensure even distribution of the pressure. This is in accord with Metzger's observations.

Other recent tests in an electrical laboratory[6] on 6in by ¼in aluminium bars confirmed that with an overlap of ten times the bar thickness stable joints are obtained with a joint efficiency less than 1, if sufficient contact pressure is developed. In this case packs of six bars were overlapped, drilled and jointed by means of five bolts ⅜in diameter in 40-ton steel, with external steel clamping plate, the surfaces being scratch-brushed under petroleum jelly. The bolts when fully tightened would be capable of developing a minimum contact pressure of 1500 lb per square inch of the projected area : an alloy steel had to be used in order to develop sufficient contact pressure, particularly on the inner bars, where it was found that contact resistance tended to be higher.

The Aluminium Development Association is engaged in a series of tests on 1in by ¼in overlapping aluminium bars, bolted with two ⅜in diameter bolts and nuts : the resistance of the joints has been measured weekly over a twelve-month period. Methods of surface preparation include filing and the use of hard particles of 50/50 copper/aluminium alloy mixed with neutral oil into a paste ; the assembly also includes copper/copper and copper/aluminium connections, and some of the joints incorporate cup (Belleville) washers. A current of 250A is passed for eight hours each day and then switched off. The atmosphere is inland industrial, contaminated with sulphurous fumes. It has been noticed that joint resistance varies from week to week for all connections, and when readings are corrected to 20 deg. Cent., the variations closely follow changes in the ambient temperature. The results after one year of testing suggest that filing of the aluminium surfaces with or without grease is a satisfactory surface preparation, giving joints of satisfactory efficiency which show no significant overall rise in resistance and compare favourably with the copper/copper joints in the same circuit. The use of hard particles without filing was fairly satisfactory, but " tinning " of the aluminium surface with solder, and electroplating with silver, were less satisfactory. The use of Belleville washers to maintain the contact pressure was not successful, but as the pressure in this instance was of the order of 1000 lb per square inch it is not surprising that the resistance of the joints rose to an unacceptable degree (the other tests reported here indicate that a pressure of at least 1500 lb per square inch is needed). The tests are continuing with modifications. Other tests on aluminium busbar connections, some silver-plated or treated with special compounds have been reported in the U.S.A., but require separate consideration and confirmation by practical experience over a reasonable period before being used as a basis for recommended jointing techniques.

Theoretical Considerations.—The experimental work so far reported may be considered in the light of modern knowledge and theory concerning the nature of contact resistance and the mode of pressure distribution in bolted joints.

Holm,[7] Windred, and others discussed the passage of current across interfaces under pressure, and postulate that as no two mating surfaces are ever perfectly flat, contact between them is inevitably local in character, and with very hard material would only be at three points. The application of pressure crushes the local asperities, increasing their area and number, although it appears that even under the maximum pressure that can be exerted, i.e. that approaching the yield stress of the material, the true contact area thus developed is many times less the apparent or measured area. Furthermore, according to Holm, current is effectively passed only at those points where the asperities have been crushed and deformed, so that true metal contact is achieved and the contact resistance is extremely low ; these points have been termed *a*-spots. The *a*-spots are surrounded by areas of less perfect contact where there may be no more than a mono-molecular layer of liquid or lubricant; the resistance at these " quasi-metal " spots is still of a low order and permits passage of the current. Outside these quasi-metal spots are areas where contact has not been achieved and tarnish films, oxides, sulphides, &c., still remain so that little or no current passes.

This theory is in conformity with the general shape of pressure/contact resistance curves such as those in Figs. 1 and 2, and it is apparent from Holm's calculations and practical tests that this sort of curve obtains for many metals and also for graphite in contact with metals. The theory is also supported by the practical

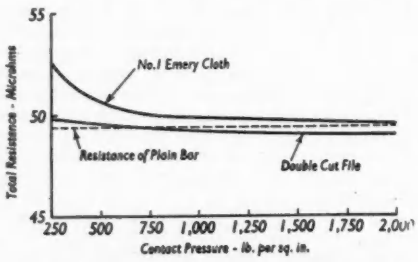

Fig. 1—Contact pressure/resistance curves for aluminium busbars (overlap 10 × bar thickness)

observation that reroughening of dismantled busbars is needed to obtain low resistance values on remaking a joint. It explains Melsom and Booth's reported difficulties in obtaining consistent contact resistance values and reproducibility of their results after pressing the mating surfaces together several times without reroughening ; presumably the initial pressure had flattened out the local asperities and any separation of the bars followed by subsequent reapplication of the pressure would not effect the same crushing action and development of *a*-spots as in the first instance. Holm's hypothesis also explains the observations of Koch that the use of petroleum jelly did not lower the measured

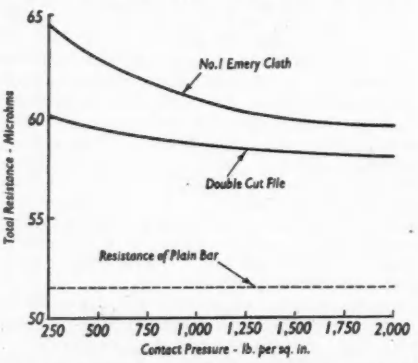

Fig. 2—Contact pressure/resistance curves for copper busbars (overlap 10 × bar thickness)

contact resistance ; the petroleum jelly would be forced away from those areas of true contact where *a*-spots and quasi-metal spots develop, leaving the residues only in the remaining areas of less perfect contact where virtually no current is transmitted in any case.

It has been shown recently that aluminium is readily pressure welded and it may well be that some actual welding occurs at the *a*-spots, giving improved contact.

It is axiomatic that the loads developed in correctly tightened nuts and bolts increase very rapidly with increase in diameter, and also with the yield strength of the bolt material. Thus, a ⅜in diameter mild steel bolt can develop a maximum proof load of less than 1 ton, whereas a ½in bolt may develop 1¾ tons. Furthermore, the distribution of the load in a bolted busbar connection is apparently such that the high pressures needed to create areas of low resistance (*a*-spots) are developed only in the zone immediately under the bolt head, and are therefore very local. Metzger's findings that small diameter bolts are not capable of developing substantial pressures between the bars are in line with this view, which also points to the desirability of using bolts of as large a diameter as possible. As is shown in the later section describing experience with aluminium busbar connections, those joints fitted with large diameter bolts have been found to remain stable in resistance over long periods.

It also follows that the higher pressures that can be achieved with high-tensile bolts will yield many more *a*-spots and a lower contact resistance, provided the stress is distributed as uniformly as possible. On the other hand, modern theory of the plastic state suggests that the true area of contact developed by a given bolt loading is proportional to the elastic limit of the bar material ; this suggests that a lower total clamping pressure should be needed for aluminium than for copper bars. In one series of tests here reported[8] lower and more reproducible contact resistance values were obtained on aluminium bars than on copper bars, under identical loadings.

If the above concept of the mode of passage of the current is valid, it follows that the inclusion of conductive materials such as hard metal particles or metal-loaded pastes is not likely to improve the performance of the joint, because the particles would tend to keep the contacting surfaces apart and prevent the development of *a*-spots. On the other hand, they could provide a means of penetrating the tarnish and oxide films on the metal surfaces so as to create a large number of small *a*-spots ; Metzger found that hard aluminium shavings introduced into the joint reduced the resistance initially, and possibly the particles pierce the surface films and enable some passage of current to take place in the zones where films remain, but probably play no part in producing the *a*-spots and quasi-metal spots that normally provide a low-resistance path. This is really a different mechanism of contact involving high local pressures and a system of stress distribution that is inherently unstable. It would possibly be more prone to relaxation than one created by the crushing down of local asperities on roughened metal surfaces, as there would not be much support at the *a*-spots where high-pressure exists.

Experience with Aluminium Busbar Installations

Practical experience with aluminium busbar installations, particularly those involving large busbars, has shown that stable joints of low resistance can be achieved either by means of heavy bolts passing through the bars or by means of strong rigid clamps tightly fitted. On the basis of Melsom and Booth's findings a large number of busbar installations have been successfully made, both in copper and in aluminium ; they have proved satisfactory in that a low contact resistance has been maintained at the joints, but in some cases the development of a high joint resistance has occurred and remedial measures have not easily been found. Thus, in 1926, a number of tests were carried out by the E.R.A.[8] on busbar installations, both in copper and aluminium, and many of these were found to have developed a high resistance. This could have arisen from irregular distribution of the total bolt load, particularly if means of pressure distribution by rigid plates or washers of large diameter were omitted. It is possible also that at that time it was not always appreciated that aluminium busbars are softer than copper bars, and therefore needed different treatment in the detailing of designs.

A few measurements were recently made on four straight-run joints in 20kA busbar circuits at an aluminium reduction plant.[9] These were installed twenty-five years ago and surfaces were prepared by hand with emery paper, no grease being used. The joint consists of ten 6in. by ¼in aluminium bars interleaved and clamped together between ¾in steel plates with four ⅞in

diameter bolts outside the busbars. The following values were recorded :—

TABLE I—*Voltage Drop Measured on Busbar Installations 17 to 25 Years Old*

Busbar	Joint	Date made	Overlap in	Drop across joint divided by drop along same length of bar
Vertical ...	I	1929	10	0·82
Horizontal	II	1929	10¾	1·05
Horizontal	III	1929	10	0·92
Horizontal	IV	1936	8	1·05

These findings indicate that good stable joints are achieved by very rigid clamps and large bolts, with an even distribution of bolting load. The overlap was perhaps greater than needed. Aluminium/copper connections were found to be a serious problem, but the atmospheric conditions in this case tend to be corrosive to aluminium, which may well account for the difficulty encountered in making satisfactory aluminium/copper connections in this particular instance.

Power Supply Substations.—Seven London substations of the Southern Region of British Railways have utilised 4in by ¼in aluminium busbars for twenty-five years, mainly in the feeder switchgear from rotary converters. The bars are subjected to varying loads rising to 750A per square inch at 660V during peak periods. During the years a number of joint failures have occurred, chiefly with stud joints, most of the interleaved or butt-spliced joints remaining perfectly satisfactory ; these include aluminium/copper and aluminium/brass connections as well as aluminium/aluminium. Efficient practical jointing methods were developed on the following lines as a result of experience.

The aluminium surfaces were draw-filed without lubricant, care being taken to maintain them as flat as possible. The direction of filing should be the same for both mating surfaces and not at right angles. A desirable surface showed considerable roughness from the filing, and as soon as filing had been completed the filings were removed with a paraffined rag and petroleum jelly was applied to the surface, thereby keeping oxidation to an absolute minimum. A prepared surface thus treated with petroleum jelly need not be bolted up immediately and this greatly facilitated assembly work. Copper bars were similarly treated.

Clamping of the joints between rigid cast iron clamping plates is preferred, said to be due to the more uniform distribution of pressure. When through-bolting was used, accurate drilling of the holes was desirable and good lining-up, taking care to keep the surfaces flat, removing burrs, and avoiding over-tightening of the bolts and consequent distortion of the flat surfaces. By these means, very satisfactory joints were achieved both in aluminium/aluminium and aluminium/copper interleaved connections. Tee joints were also made in a similar manner. Because of the high current densities, the ends of bars in single overlap joints were chamfered.

Stud joints proved troublesome at first, as the design did not permit sufficient contact area and readily led to distortion of the flat surfaces of the bars with further loss of contact area. One example is a 1¼in by ¼in bar connected to a brass lug with a single ¾in diameter stud. Constant retightening was ineffective, but good joints were finally achieved by backing the joint with hard, stout copper plates that supported the whole width of the aluminium bar on both surfaces and provided a more uniform distribution of contact pressure. It appears from the above practical experience that the use of bolts of too small a diameter, the provision of insufficient contact area, inadequate surface preparation, or poor joint design that permits loosening under thermal stress, are amongst the factors that can lead to unsatisfactory performance. On the other hand, correction of these factors yielded satisfactory joints.

Telephone Exchanges.—The G.P.O.[10] has made available test data from several installations of aluminium busbars in battery rooms and power plant, some of them of long standing. At three exchanges using aluminium bars 6in by ¼in, 4in by ¼in and 2in by ¼in, installed 1952–53, the millivolt drop at full load across the joint was compared with that across the same length of plain bar. Both on the positive and the negative side the joint efficiency thus measured was less than 1 on seven out of eight joints at one exchange, varied from 1 to 2·2 at a second exchange, and was 1 or less on seventeen out of twenty-eight joints in the third case, no joint having an efficiency worse than 1·3/1. The joints were clamped or through-bolted, the surfaces being scratch-brushed or treated with No. 0 emery cloth. It was concluded that this treatment was satisfactory, but that a good standard of workmanship was an important factor.

The aluminium busbars installations at Terminus and Mayfair exchanges, London, have also been tested, having been installed twenty-one years ago. The average efficiency of the joints tested at Terminus were 1·26/1 ; at Mayfair, certain joints gave worse results than this, and the current distribution in them was bad. On the other hand, all joints on the positive side had a joint efficiency less than 1/1. It was concluded that the design of some of the joints was not ideal, and that for a new and properly designed installation there should be no difficulty in achieving and maintaining 1/1 joints, using the conventional filing or scratch-brushing technique as laid down in B.S. 159.†

RECOMMENDATIONS FOR JOINTING ALUMINIUM BUSBARS

Taking into account the experimental results reported above, the theoretical considerations, and also the observations on actual busbar installations over a number of years, the following recommendations are put forward for making bolted busbar connections in aluminium and for aluminium/copper connections : due attention to them can, therefore, be expected to yield joints of low resistance which will remain immune from the effects of temperature changes and corrosive action over long periods.

Surface Treatment.—It is essential to remove the oxide film from the aluminium before the connection is made. This can be effectively done by cross-filing either dry or under a neutral oil or petroleum jelly, which should be of good quality, free from water. A power-operated scratch brush or emery cloth is also suitable, but the use of a file card or hand scratch brushing gives less consistent results. The oil or petroleum jelly contaminated by the filings may be wiped off before assembly of the joint. It is preferable to bolt up the joint shortly after preparing the surfaces, but if assembly is not to be carried out for some time it is advisable either to leave the residues on the surface to prevent oxidation or to wipe off and apply a clean film of oil, petroleum jelly or paraffin. The merits of such surface treatments as silver plating of the aluminium busbars, tinning, the use of hard particles in the joints, or of bimetallic inserts, remain to be further explored before their true value can be assessed. Insufficient experience is available regarding such processes to enable recommendations to be made at this stage, whereas it is known that the above surface preparation based on experience over many years in service can be relied upon if properly carried out to give joints that perform satisfactorily over long periods.

Contact Area.—A generous contact area or overlap should be provided and a satisfactory working figure is an overlap of approximately ten times the bar thickness in the case of straight busbar connections ; this gives an efficient joint as regards both electrical effects due to distortion of the path followed by the current, and also as regards contact resistance. In the case of stud joints, it is desirable to provide a generous area of contact, and if possible to use bolts of a larger diameter than would be normal for copper. It is important to provide good backing to the stud and to insert a wide thick washer under the nut or bolt head so that the bolting pressure is evenly distributed. Stud joint designs for copper may not be satisfactory in aluminium, and it may be desirable to increase the contact areas and general sturdiness of the connection.

Contact Pressure.—It is estimated that a contact pressure of at least 1500 lb to 1750 lb. per square inch of the projected contact area is needed to give a stable joint of low contact resistance. The size and the number of the bolts therefore depends on the projected contact area, and may be first estimated from Table II, which gives the loading achieved with various sizes of bolts. Bolts should be tightened evenly, of course, and the use of a torque spanner may be helpful in this respect. Theoretically, the onset of plastic conditions at the interfaces leads to almost perfect contact, and the theoretical contact area developed with different sizes of bolt is indicated in the last column of Table II. These zones are located immediately under the bolt heads, and increase rapidly in area with increasing bolt size ; this should be taken into account when deciding the number and the size of the bolts to be used in a connection.

† Now under revision.

TABLE II—*Maximum Bolting Loads Achieved With Bolts of Aluminium Alloy or Mild Steel (of at Least 15 tons per sq. in. Proof Stress, B.S.W. Threads).*

Bolt diameter, in	Maximum proof load in bolt, tons	Stress in bolt, tons/in²	Theoretical contact area achieved on aluminium bars under plastic conditions, sq. in.
½	0·98	14·4	0·181
⅝	1·74	14·4	0·323
¾	2·72	13·35	0·505
⅞	3·92	12·9	0·725
1	5·27	12·5	0·925
1	6·96	12·6	1·00

NOTE 1.—B.S.F. threads give slightly higher values of maximum proof load.

NOTE 2.—Stronger bolt materials of higher proof stress give correspondingly higher maximum proof loads and greater theoretical contact area.

Bolt Spacing.—In general, on square connections, five bolts located one at each corner and one in the centre gives a satisfactorily even pressure distribution, the bolts preferably being as large as space permits. For some rectangular overlapping joints, six evenly spaced bolts may be more suitable, but this grouping is not necessarily as efficient.

Bolt Materials.—The loads given in Table II are for bolts which have a proof stress or elastic limit of at least 15 tons per square inch, and when fully "stressed," develop a certain load termed the maximum proof load. Mild steel and certain aluminium alloys are in this class of material. If a stronger bolt material is used, such as high-tensile steel, the maximum proof load developed is considerably greater and there is a corresponding increase in the theoretical contact area. Where the projected area is limited by external factors, or by a particular design, it may therefore be desirable to use high-tensile steel bolts. High-tensile steel bolts are of special value for runs where there is interleaving of a number of parallel bars, as sufficient pressure can then be developed at the contacting surfaces in the centre bars. Where long bolts are used, consideration should always be given to the use of bolts with reduced shanks, so that even stretching of the bolt will give more uniform distribution of stress in the bolt and thence the bars.

Clamping Plates.—Improvement in the distribution of pressure which otherwise tends to be concentrated immediately under the bolt heads can be accomplished by the use of rigid external plates or clamps on the outer bars under the bolt heads and nuts. These plates may be of steel, cast iron or aluminium alloy ; and are preferable to large diameter washers, being more effective in achieving a uniform distribution of pressure. Clamps also improve distribution of pressure even when mild steel or aluminium alloy bolts are used, although the effect is less marked, as the bolt loadings are lower. For small sizes of bar, where through bolts can only be of a small size, adequate pressure may not readily be developed, and the use of clamping plates with external bolts becomes more efficient. There can be no definite size of bar above which through-bolting should be used and below which clamping should be employed ; the line of demarcation depends on the particular design, the chosen bolt material and other factors.

Protection Against Corrosion.—B.S. 159 requires that aluminium/copper connections should be protected from the atmosphere, and this becomes essential when the joint is out-of-doors or exposed to corrosive environments. The connections may be painted with zinc chromate primer and top coats, or with bitumen

paint, or otherwise protected as by taping with plastics. Aluminium/aluminium joints do not normally require protection, and may be treated like copper/copper joints.

Re-Assembly of Dismantled Joints.—When a bolted joint has been dismantled, it is always necessary to refile or otherwise prepare fresh mating surfaces before assembling the joint once more.

Workmanship.—The making of busbar connections, whether in copper or in aluminium, is no rough-and-ready operation, and experience has shown that a good standard of workmanship needs to be observed in drilling, filing or scratch-brushing, fitting and assembly, in order to achieve trouble-free service. Holes should be accurately drilled and lined up and burrs removed ; bolts should be tightened uniformly and with even tension, preferably with the aid of a torque spanner.

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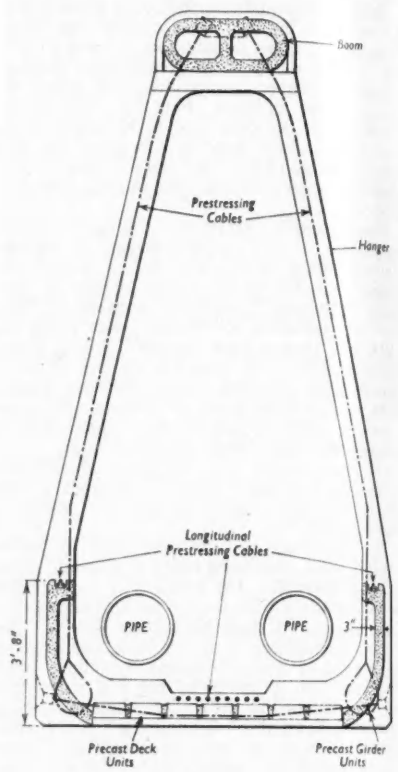
Gunthorpe Pipe Bridge

A PRESTRESSED concrete bridge, shown in the accompanying illustration, has been built at Gunthorpe, near Nottingham, to carry water mains across the River Trent. Traffic on the river had to have free passage during construction, so a bridge sufficiently light to be built on the bank and then launched across the river was needed. An open web bowstring design in prestressed concrete was decided on. The bowstring is designed with a single top boom, a bottom tie member consisting of two stiffening parapet girders with a light deck between, and triangular hangers joining these members. The abutments are vertical slabs of prestressed concrete. The bridge has a single span of 250ft (the river is 234ft wide at this point) and an overall width of 10ft ; the clear deck width is 7ft 9in. The soffit of the deck is 20ft above the normal summer level of the river and the rise at mid-span between deck and boom is 28ft.

The two 21in diameter water pipes are made in 25ft lengths and the design of the bridge was based on this dimension ; they are actually carried by the concrete hangers, which are placed at 25ft centres coinciding with the joints in the pipes. The boom and girders were built in 25ft bays between the hangers. Each hanger is prestressed with one twelve-wire Freyssinet cable. The arched boom section is a hollow rectangle with rounded ends with 3in thick walls and a 3in thick central web ; it is 3ft 4in wide and 1ft 4in deep overall. Each of its ten structural bays is made of four sections of precast concrete, each approximately 6ft long, which were assembled and stressed together on the ground with one twelve-wire Freyssinet cable. When completed each bay was lifted into position and no further prestressing was applied to the boom as a whole. At either end the boom divides into two solid arms, circular in section, which are cut away to fit over the pipes and allow them free passage through the end block and into the abutment. These arms bear on Freyssinet hinges on the end block. The end blocks themselves are of heavily reinforced concrete cast *in situ* and prestressed in the transverse direction with fourteen twelve-wire Freyssinet cables. A single slender boom of 250ft span needs some form of bracing if it is not to buckle ; mild steel bars crossing diagonally between the hangers have been used to provide this—they are protected against corrosion by zinc-rich paint.

The deck and girders together form the tie member. Like the boom, the prestressed concrete girders are made of four precast sections, approximately 6ft long, within each bay. The tie member is braced by precast prestressed concrete units spanning between the girders, and at the joints between the 6ft sections within each bay. The former were stressed with a twelve-wire and the latter with a two-wire Freyssinet cable. As the weight of the pipes is taken by the hangers, the deck itself could be designed to carry only such light and occasional loads as those of foot traffic or snow. It was constructed with "Shishkoff" hollow units of precast concrete, about 6ft long, spanning between the transverse braces.

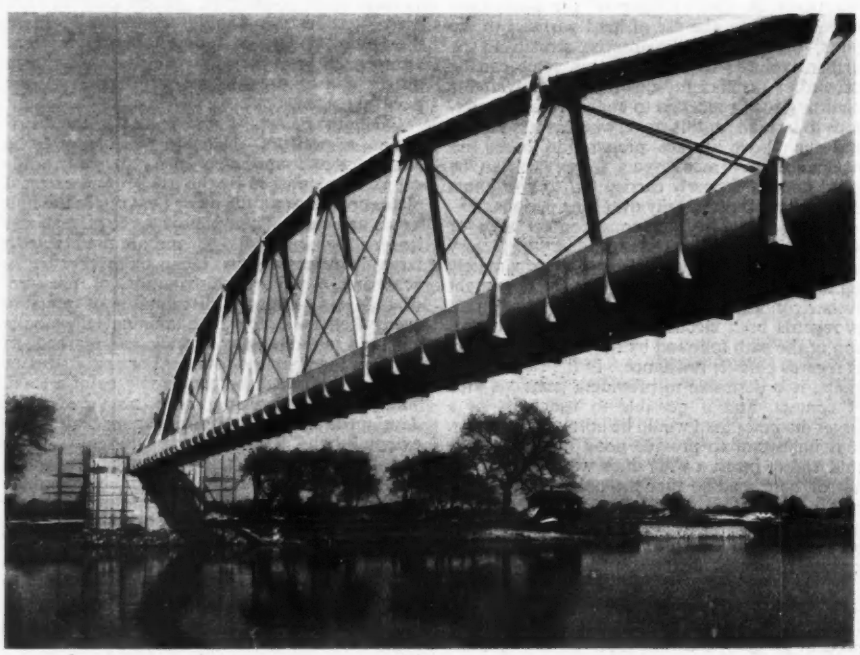
When the deck and girders were assembled they were prestressed together with fifteen twelve-wire Freyssinet cables, three of which lay in the groove in the top flange of each girder and the other nine centrally on the "Shishkoff" units. The anchorages of these cables are contained in the end blocks. A concrete screed was then laid over the units and the cables. The bridge was built on the north bank of the river, and then launched across it and supported on temporary steel abutments at a height of 5ft above its final level. This was done so that it could finally be placed on the permanent supports without any sideways movement which might have set up unpredictable stresses. The weight of the structure carried across the river was nearly 200 tons.



Cross section of prestressed concrete pipe bridge

The specification for the concrete demanded a minimum strength of 6000 lb per square inch at twenty-eight days, except for the end blocks, where a minimum strength of 8500 lb per square inch at twenty-eight days was required. Ultrasonic tests were carried out on the concrete of the boom to determine the modulus of elasticity so as to verify the buckling calculations. In testing the completed bridge water from the river was pumped into the box formed by the end blocks, parapets and deck to 1·25 times the working load ; the deflection was 1¼in. There was complete recovery when the load was removed.

The bridge was built for the Water Department of the City of Nottingham ; the city engineer of Nottingham undertook the supervision of the work. The design was by the Pre-Stressed Concrete Company, Ltd. ; Crowley, Russel and Co., Ltd., was the main contractor ; the Croft Granite Company, Ltd., was subcontractor for the precast concrete ; the Franki Piling Company, Ltd., drove the piles. The ultrasonic testing was carried out by the Cement and Concrete Association.



Pipe bridge over the River Trent at Gunthorpe, near Nottingham

SYMPOSIUM ON WINTER CONCRETING.—A symposium on the theory and practice of winter concreting is to be held in Copenhagen in February, 1956. The organisers invite written communications for the symposium. The principal topics concern definitions and characteristics of weather conditions, laboratory experiments for determining the resistance of concrete to early freezing, the influence of temperature on the hardening of concrete, resistance of concrete to frost at early ages, control of concrete quality and practical methods of winter concreting. Visits to constructional sites are to be arranged. Further details may be obtained from the organising secretary, R.I.L.E.M. Symposium, 1956, c/o The Danish National Institute of Building Research, 20, Borgergade, Copenhagen, K., Denmark.

Oil Film Extent in Complete Journal Bearings*

By J. A. COLE, M.Sc., A.M.I.Mech.E., and C. J. HUGHES

Work on oil film extent in complete journal bearings at the Mechanical Engineering Research Laboratory yielded two anomalous findings : that the friction was invariably lower than that calculated on the basis of a continuous film, and that the test bearing, which was free to tilt, gave different attitude-eccentricity loci at its two ends. This has led to an investigation of temperature distribution in journal bearings and of film extent in journal bearings, and some preliminary results of the second item are reported here.

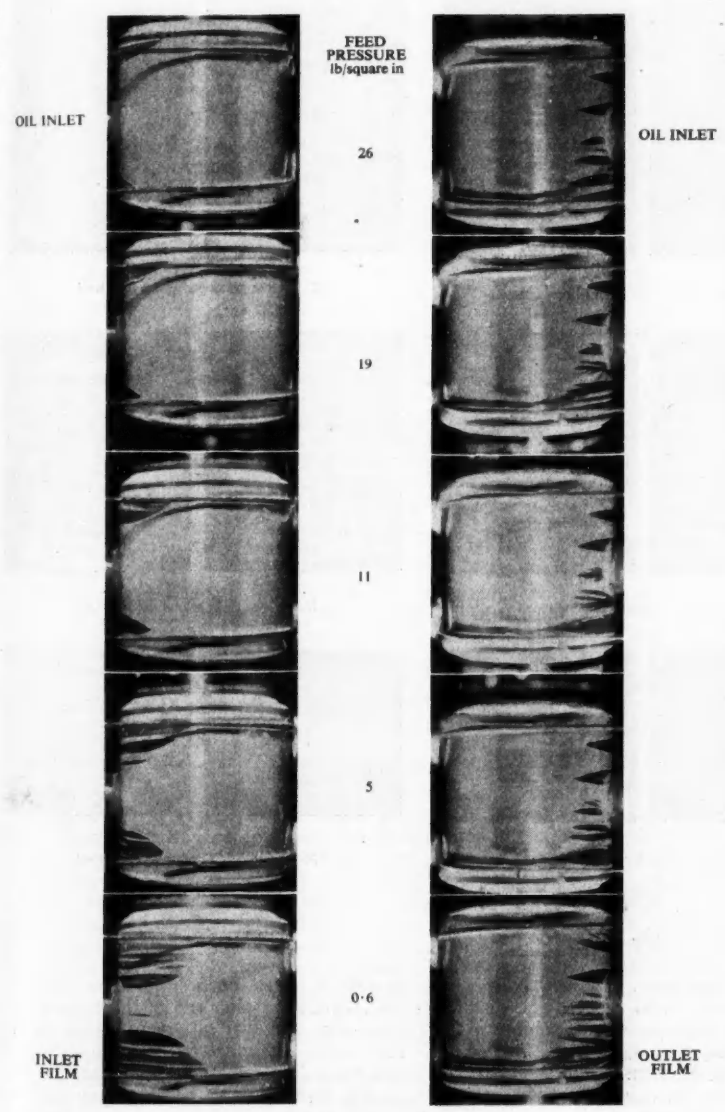
Earlier Investigations of Film Extent

THE extent of the load carrying film in a complete or 360 deg. journal bearing may be determined by measurements of film pressure at a number of pressure tappings in the bearing surface, but this method is not likely to give satisfactory results in the low pressure regions of the film. Direct visual observation of the film is more promising, and results of its use have been published by Skinner,[2] Hamilton Gibson,[3] Hyde,[4] Barnard,[5] Vogelpohl,[6] Kolano,[7] and Banks and Mill.[8] Only Barnard, Vogelpohl and Kolano dealt with complete journal bearings, and they do not appear to have made extensive use of visual observation to study a wide range of variables with reasonably practical values of clearance, speed and load.

A satisfactory method of photographing oil film extent in complete 1in diameter bearings with standard clearance ratios (usually 0·001 and 0·002) has been developed at M.E.R.L., and measurements of film extent, oil flow and oil inlet and outlet temperatures have been made with a variety of conditions. Glass bearings are used, and the oil film is made to fluoresce by ultra violet irradiation. The lubricant is a light mineral oil, viscosity about 6 centipoises at 60 deg. Cent. Speeds up to 5000 r.p.m. and loads up to 200 lb per square inch of bearing projected area have been employed. It is proposed to discuss the photographic results qualitatively here.

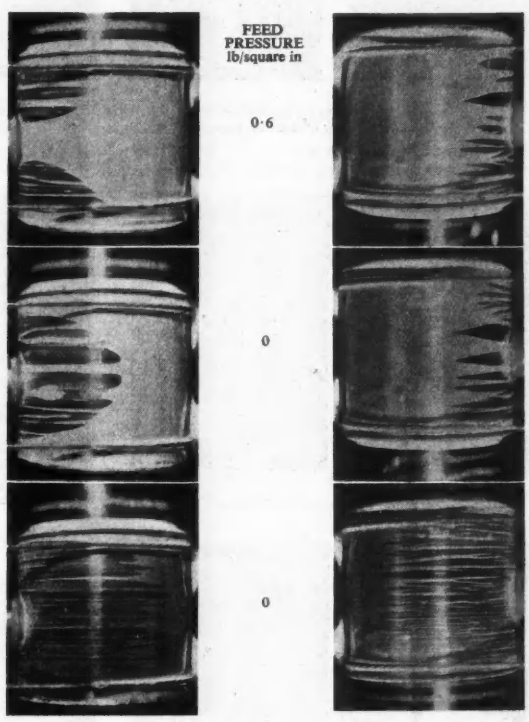
The Single Hole Oil Entry and the Effect of Supply Pressure

One of the simplest types of bearing is the complete bush with a single oil hole to admit oil opposite the point of application of the load. Fig. 1 shows a bearing 1in length by 1in diameter by 0·002in diametral clearance running at 1250 r.p.m., and 40 lb per square



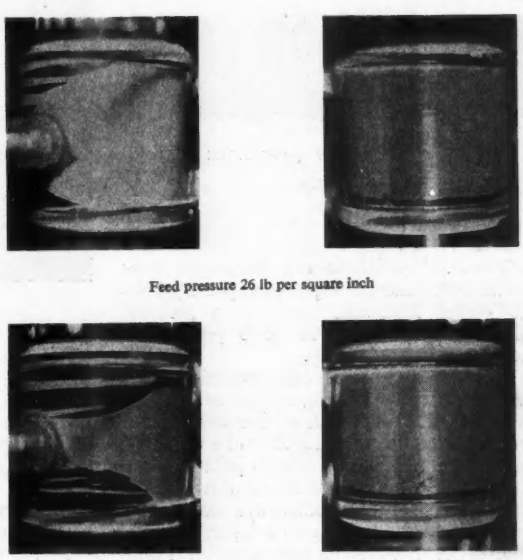
1240 r.p.m. 40 lb per square inch load

Fig. 1



1250 r.p.m. 40 lb per square inch load

Fig. 2

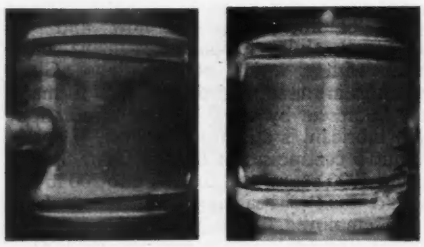


Feed pressure 26 lb per square inch

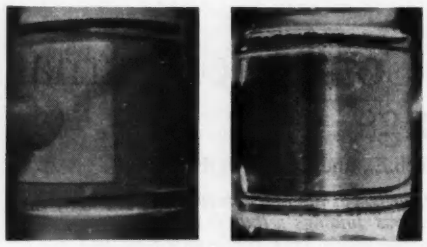
Feed pressure 0·6 lb per square inch

Fig. 3

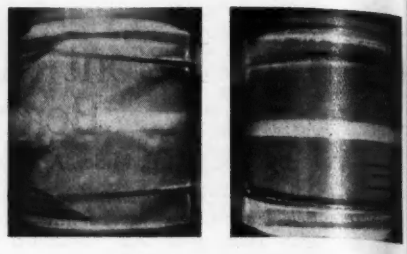
* Communication from Mechanical Engineering Research Laboratory.



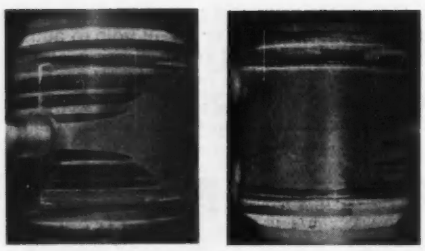
Feed pressure 26 lb per square inch
1000 r.p.m. 30 lb per square inch load



Feed pressure 26 lb per square inch
1000 r.p.m. 30 lb per square inch load

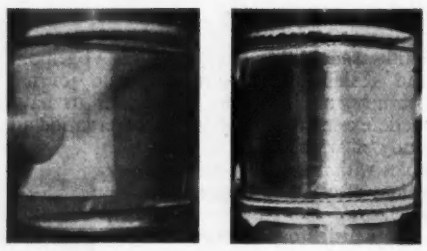


Feed pressure 26 lb per square inch
1000 r.p.m. 30 lb per square inch load



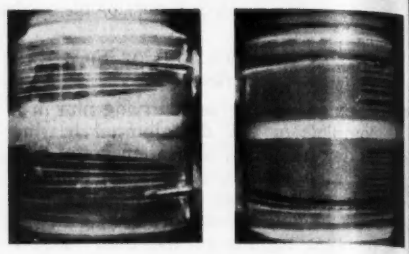
Feed pressure 0·6 lb per square inch
1000 r.p.m. 30 lb per square inch load

Fig. 4



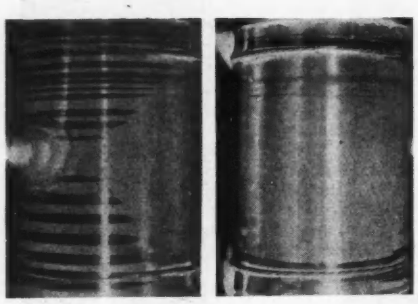
Feed pressure 0·6 lb per square inch
1000 r.p.m. 30 lb per square inch load

Fig. 5

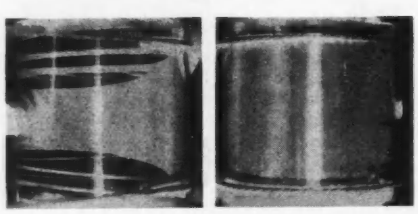


Feed pressure 0·6 lb per square inch
1000 r.p.m. 30 lb per square in load

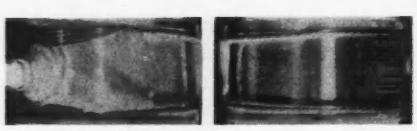
Fig. 6



750 r.p.m. 93 lb per square inch load



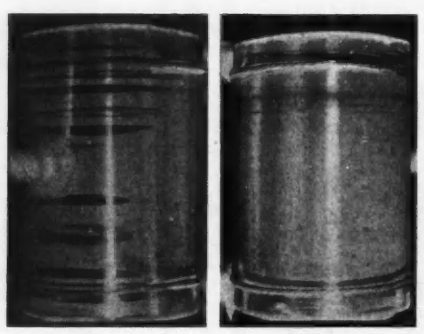
500 r.p.m. 56 lb per square inch load



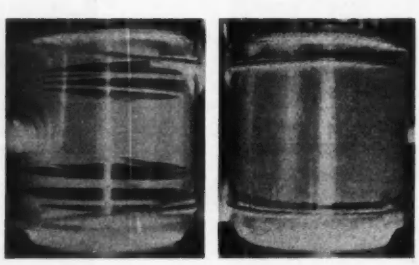
500 r.p.m. 87 lb per square inch load

$\frac{ZN}{P} \div 120$

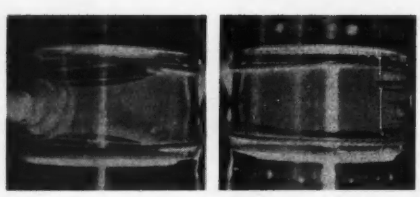
Fig. 7



2250 r.p.m. 93 lb per square inch load



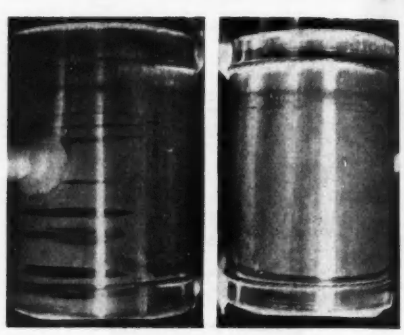
500 r.p.m. 28 lb per square inch load



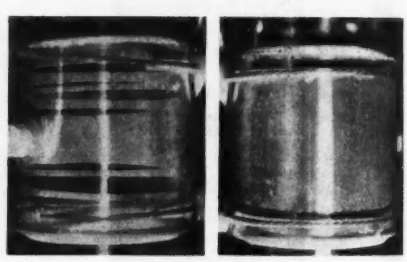
1500 r.p.m. 87 lb per square inch load

$\frac{ZN}{P} \div 235$

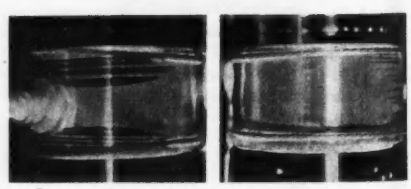
Fig. 8



2250 r.p.m. 56 lb per square inch load



1500 r.p.m. 56 lb per square inch load



3000 r.p.m. 87 lb per square inch load

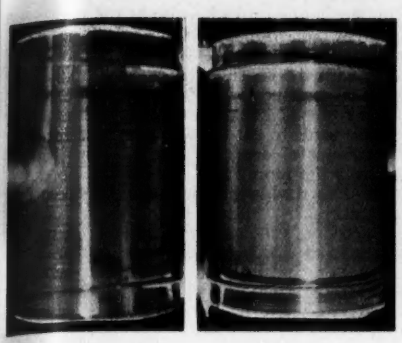
$\frac{ZN}{P} \div 350$

Fig. 9

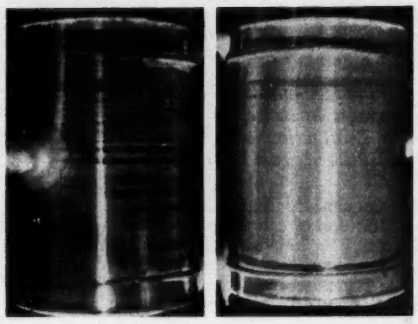
inch load. The left-hand photographs show the inlet film and the right-hand photographs the outlet film, and the supply pressure increases from 0·6 lb to 26 lb per square inch from bottom to top.

The inlet pattern is characteristic of the single hole entry bearing under load, a film extending the full width of the bearing not forming for some distance after the oil entry, the amount depending on the operating conditions. The outlet film breaks down as the film diverges forming numerous streaks which travel round the bearing to re-enter the inlet film. The pattern flickers through minor variations while the bearing is running, but is fixed in its main outline for a given set of operating conditions. The effect of raising the feed pressure is to shorten the distance taken for the inlet pattern to achieve a full width film and, to a far smaller degree, to lengthen the outlet film.

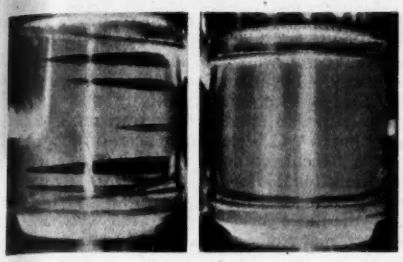
Fig. 2 shows the effect of cutting off the oil supply altogether. The characteristic inlet pattern is replaced by an inverse pattern in which the inlet film is supplied with oil from the meniscus at each end of the bearing, and the end leakage oil recirculates to the meniscus. Eventually the meniscus fails, and the inlet and outlet films shorten drastically, although the bearing may continue to run under fluid film conditions for some time. A drip feed produces an alternation



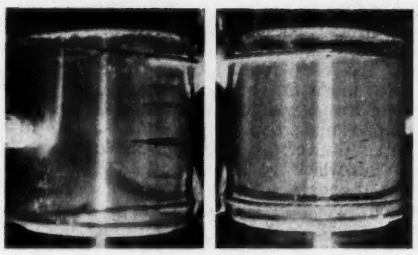
2250 r.p.m. 28 lb per square inch load



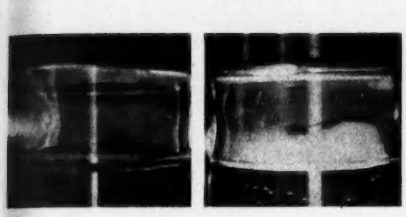
2250 r.p.m. 10 lb per square inch load



500 r.p.m. 10 lb per square inch load

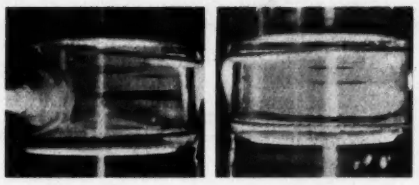


1500 r.p.m. 10 lb per square inch load



5000 r.p.m. 52 lb per square inch load
$\frac{ZN}{P} \div 700$

Fig. 10



1500 r.p.m. 9 lb per square inch load
$\frac{ZN}{P} \div 2000$

Fig. 11

between the first and the second or third of these film patterns.

Comparison of Oil Entry Systems

Fig. 3 shows the single hole oil entry already discussed, at a low and a high feed pressure. The loading cables are now at 45 deg. to the plane of the photographs to show inlet conditions more plainly. Fig. 4 shows a single hole oil entry with an axial groove extending over 75 per cent of the bearing length. At the low feed pressure, 0·6 lb per square inch, the groove does not perform its intended function, and the oil entry pattern is characteristic of the single hole only. At the high feed pressure, 23 lb per square inch, the axial groove gives a full width inlet film, and this extends back a little into the outlet film. Fig. 5 shows a single hole oil entry with the bush relieved over an angle ± 45 deg. for 75 per cent of the bearing length, in the manner of a very wide axial groove. This gives a substantially complete film at both feed pressures, although at 0·6 lb per square inch the trailing edge of the relieved area does nor run full. This oil entry system gives the most oil flow for given operating conditions of the four systems described here. Fig. 6 shows a single hole oil entry with a complete circumferential groove. This gives a surprisingly short full width film even at the higher feed pressure. Adjacent to the groove a narrow complete circumferential film is maintained.

Although the loads and speeds are similar in these photographs, variation of temperature with oil flow alters ZN/P to a small extent, and this, combined with the loading produced by the higher feed pressure, will cause the running eccentricity ratios to vary.

The Effect of Operating Conditions and Length/Diameter Ratio

The remaining photographs, Figs. 7–11, show three bearings, clearance ratio 0·001, length-diameter ratios $\frac{1}{2}$, 1, $1\frac{1}{2}$, with a single oil hole of fixed diameter, under various conditions of load and speed and with a feed pressure of 6 lb per square inch. It has been found that the film pattern is, as would be expected, primarily determined by eccentricity ratio for a given feed pressure, and the three bearings are therefore compared on a ZN/P basis† (Z centipoises, N r.p.m., P lb per square inch load). In Fig. 7, ZN/P equals 120 and the bearing is fairly heavily loaded ($ZN/P \sim 20$ would be very roughly the limit of hydrodynamic lubrication here). The full width film extends not a great deal over 180 deg., in reasonable agreement with the conventional assumption already mentioned. However, the equivalent area of the broken film is probably less than half that normally assumed in the same theory when calculating the viscous drag due to the low pressure region. Friction and temperature measurements are needed to investigate this further. Although the film patterns are similar for the three bearing lengths, the film extent does vary with length-diameter ratio.

As the loading decreases and ZN/P rises, the arc of the full width film lengthens, although this is masked in the photographs by the movement of the minimum film thickness position with changing eccentricity ratio. The full width film now starts later and finishes later than the theory suggests. At very high ZN/P, over say, 1000, especially with the two shorter bearings, the film is nearly complete apart from a few long bubbles in the centre, and here a speed effect is noticed, shaft rotation removing oil from the inlet film more rapidly than it can be supplied from the oil hole. In the longest bearing film breakdown is of this type but randomly distributed across the inlet film in Figs. 10 and 11.

† Sommerfeld number
$= 2{\cdot}415 \times 10^{-9} \times ZN/P \div$ (clearance ratio).[3]

Conclusion

The photographs permit a detailed examination to be made of the effect of running conditions and bearing shape on film formation and rupture in journal bearings, and the present qualitative survey will be followed by a quantitative study of the subject, relating film extent, friction and oil flow. Preliminary indications are that the full width film begins and finishes somewhat later than is assumed in conventional theory. Under conditions of high speed and low load, the film is practically complete. The outlet film, usually described as cavitated but assumed to be continuous when calculating its viscous drag, is shown to consist of filaments of oil covering only a fraction of the film. The shape of the entry film, as influenced by oil entry conditions, is clearly shown.

Acknowledgments

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[2] Skinner, S., 1905, *Proc. Phys. Soc.*, Vol. 19, pages 73–80.
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[4] Hyde, J. H., 1920, Report of Lubricants and Lubrication Inquiry Committee, D.S.I.R., Appendix 16, pages 113–114.
[5] Barnard, D. P., 1926, *Ind. and Eng. Chem.*, Vol. 18, pages 460–462.
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Short Notices

Solutions of Problems in Surveying and Field Astronomy. By H. W. Stephenson, A.M.I.C.E. London: Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, W.C.2. Price 25s.—The author has endeavoured to include in this volume, which comprises a collection of solutions of typical problems in surveying, geodesy and field astronomy, an example of every type of problem likely to be met with in the engineering degree examinations of British universities. The examples given are of recent date. The book also includes a list of essential formulæ, and each chapter begins with a brief outline of the theory with which it is concerned, before giving typical worked examples of problems.

Mechanical and Electrical Equipment for Buildings. By C. M. Gay, C. D. V. Fawcett and W. J. McGuinness. London: Chapman and Hall, Ltd., 37, Essex Street, W.C.2. Price 68s.—The third edition of this American textbook has been revised to include modern practice in the United States, in the selection, installation, operation and maintenance of electrical and mechanical plant in buildings. The principal classes of equipment dealt with concern water supply, sanitation, heating, air conditioning, electrical equipment and acoustics.

Canals and Inland Waterways

In our issue last week, we printed a summary of the recommendations made by the Board of Survey of canals and inland waterways in its report to the British Transport Commission. Here we give some information on the history and contemporary conditions of the canal system, abstracted from the Board's report.

THE use of rivers for inland navigation is of great antiquity. The history of artificial waterways in this country—that is to say, of canals as distinct from canalised rivers—may be said to begin with the construction of the first Bridgewater Canal to carry coal from Worsley to Manchester, which was opened on July 17, 1761. This proved so successful that the construction of other canals followed rapidly, and the period from 1760 to 1830 has been known as the "canal era." By the latter date, the year of the opening of the Liverpool and Manchester Railway, the whole of the canal system as it exists to-day, with the exception of the Manchester Ship Canal and a few minor branches, had been completed.

With the advance of the railways the waterways lost the monopoly of inland goods traffic which they had previously enjoyed, and their position began to deteriorate. As railway competition developed, many were reduced to a precarious position. Efforts by Parliament to improve the competitive position of the canal companies by enabling them to vary their tolls, to become carriers of goods and to make working arrangements proved unsuccessful, and ultimately, in many cases at the instance of the canal companies themselves, about one-third of the total mileage then existing passed to the control of the railways. This occasioned much disquiet, and during the second half of the nineteenth century several public inquiries took place, but without any tangible result. Ultimately, towards the end of the century, a persistent demand for a comprehensive inquiry culminated in the appointment in 1906 of the Royal Commission on Canals and Waterways.

The most important recommendation made was that there should be set up by Act of Parliament a central "Waterway Board," financially supported by the State. The routes which it was suggested should first be acquired and improved where those forming the "cross," linking the Midlands with the Thames, the Humber, the Mersey and the Severn. These routes had a main line length of 533 miles, and with branches a total length of 904 miles. Detailed estimates were included of the cost of improving these waterways so as to provide alternatively for 100-ton and for 300-ton vessels on the canal portions of the route, as well as for vessels carrying 750 tons on the Trent below Nottingham and the Severn below Worcester, 600 tons on the Severn between Worcester and Stourport, and 1200 tons on the Gloucester and Berkeley Canal. The weight of the dissentient voices and the criticism, possibly assisted by a general lack of public interest in the subject, all helped to prevent any definite action being taken on the lines suggested by the Royal Commission.

The Government control of the railways during the 1914–18 war included the railway-owned canals, but the independent canals were at first left uncontrolled. The carriers on the independent canals found it increasingly difficult to obtain traffic, and their trade rapidly fell away. In order that all the inland waterways might be used to the greatest possible extent in the national emergency, the principal non-railway-owned canals were in 1917 placed under the control of a Canal Control Committee of the Board of Trade. The Committee sought to organise traffic on these canals with a view to relieving the congestion on the railways, and a result of their efforts was a considerable increase in the amount of traffic carried and an improvement in the speed of conveyance, until it compared on the whole not unfavourably with that of heavy traffic on the railways.

After the 1914–18 war, the canals were returned to their owners, and it soon became apparent that their difficulties were even greater than before the war. A departmental committee on inland waterways was accordingly set up by the Minister of Transport in 1920. The committee came to the conclusion that, owing to the further deterioration of canals and to post-war increases in costs, the 1906 Royal Commission's scheme was impracticable. In its place they suggested an amalgamation of the various undertakings into a series of groups owned and administered by public trusts. Again nothing was done to implement these recommendations. In the years which followed there was a considerable growth of road traffic which affected both the railways and the waterways, and in 1930 a Royal Commission was appointed to consider the problems which had arisen; the Commission suggested that the four routes forming the "cross" system might first be amalgamated under four public trusts, with ultimate fusion of the four into one large group.

Apart from certain specific schemes of improvement, of which the Trent and the Grand Union from London to Birmingham are notable examples, nothing had been done to remedy the condition of the waterways down to the opening of the second world war. On this occasion also the waterways suffered loss of staff and were at first left uncontrolled. It was not until 1942 that they were brought under unified direction. Partly owing to the diversion of shipping to the west coast ports, traffic declined until, as the war ended, the annual carryings were about 10,000,000 tons. The waterways were still at about this lowest-ever level when, in 1948, they passed direct from Government control to the British Transport Commission.

The waterways transferred to the Commission came from three sources :—

	Miles
(i) The hitherto independent undertakings (seventeen in number, excluding such waterways as the Bridgewater and Rochdale Canals and the Thames Conservancy)	1138
(ii) Railway-owned or controlled undertakings...	965
(iii) Government-owned waterways (the Caledonian and Crinan Canals in Scotland)	69

Some 1129 miles are river navigations and broad navigations which take craft having a carrying capacity of from 50 to 400 tons. There are some 1043 miles of narrow canals which take boats 7ft wide with a load varying from 25 to 30 tons. Of the total mileage some 266 miles have been formally closed or abandoned, while a further 486 miles are no longer used by commercial traffic—a total of 752 miles, or about one-third of all the Commission's waterways.

During the six years from 1948 to 1953 well over £1,000,000 was spent on making good arrears of maintenance and £500,000 on additional plant and equipment. The total traffic increased from about 10,000,000 to nearly 13,000,000 tons per annum.

Standard of Maintenance

The waterways, as they exist to-day, remain in practically the form in which they were constructed nearly 150 years ago, with all the limitations imposed by differences in gauge upon the use of craft (length, width and depth). Such improvements as have been carried out in the past have been principally on the rivers, canalised rivers, and broad waterways, the bodies controlling these undertakings alone having the financial resources necessary for that purpose, the main exceptions being the London-Birmingham route of the Grand Union Canal. The waterways on the whole never enjoyed an income which would encourage them to set a high standard of maintenance, and the railways who owned or controlled about one-half of the waterways had no inducement to make them pay. Though they were statutorily obliged to maintain them, the amount of maintenance was generally the minimum, and the railways were pursuing a policy of abandonment where they could. The results are apparent over the whole of the waterways system, though they are less evident on the active and more prosperous sections.

Our broad conclusion is that on the main waterways further and very heavy expenditure is required, and in no direction is the need more apparent than in that of remedying the effects of erosion. The introduction of power-driven craft, with the considerable wave formation set up in a confined water space, causes extensive erosion of the banks and towing-paths. This erosion tends to silt the waterway and increases the amount of dredging required. In the case of rivers the more rapid run-off due to causes other than navigation must also be taken into account.

The cost of protective works is very heavy and ranges from £2000 (A.R.P. sheeting) to £4000 (concrete piling) per mile for the narrow canals to as much as £25,000 per mile for the broader waterways and rivers, where steel piling is necessary.

Carrying Agencies

The carrying of traffic on the waterways is undertaken partly by the Commission and partly by independent carriers (generally known as byetraders), who pay tolls for the use of the waterway. Such carriers include bodies like the British Electricity Authority and the oil companies who operate their own craft, corresponding to "C"-licensed vehicles on the roads.

It is difficult without special investigation to form any reliable estimate of the total number of craft using the waterways, as no statistics are kept of those belonging to the independent carriers, many of which are used on tidal waterways and may appear on the Commission's waterways at infrequent intervals. According to a return compiled in 1951, when inquiries were made from the individual carriers, they owned 2800 craft in all (excluding the primarily estuarial craft referred to). Of these 1100 were wide and 1700 narrow, with an aggregate carrying capacity of 185,000 tons. The Commission have 246 power-driven craft, of which 47 are wide and 199 narrow, and 1012 dumb craft (including 647 compartment boats), of which 697 are wide and 315 narrow (including 140 employed by British Railways on collection and delivery services in the Birmingham area). The total fleet numbers 1258, with a carrying capacity of 44,227 tons.

The Commission, therefore, own rather less than one-third of the craft and rather more than one-fifth of the carrying capacity. The independent carriers transport approximately 85 per cent of the commercial traffic, but they keep to certain recognised spheres of activity, in relation to both the waterway and the commodities carried. So far as general merchandise is concerned, they generally confine themselves to the wide waterways and rivers, leaving to the Commission most of the long-distance carriage of general merchandise on the narrow canals, i.e. from London to the Midlands and from the Mersey to the Midlands. The Commission do, however, carry general merchandise in wide boats on the Trent, the Aire and Calder and the Severn Navigations and the Leeds and Liverpool Canal. The carriers enjoy a virtual monopoly of the barge traffic in coal.

Conclusions and Recommendations

We recommend the establishment within the Commission of a separate organisation to deal with the waterways, under the control of a general manager who would be able to give them his undivided attention. The next steps, in our view—and to these we attach the greatest importance—must be to concentrate on those activities which are of real value as part of the transport system, and to relieve the Commission of the remainder, which are placing a heavy burden upon the waterways administration and finances.

We agree with the statement published by the Commission in 1950 that inland water transport is specially suitable and efficient for :—

(*a*) Traffic imported and for shipment in the ports connected with the inland waterway system, particularly in those instances where overside delivery from ship to barge or vice versa takes place.

(*b*) Traffic which can be carried from point to point in barge-loads.

(*c*) Traffic conveyed to or from waterside premises.

(*d*) Petroleum and liquids in bulk.

(*e*) Traffic requiring bulk movement and storage in the canal-side warehouses.

(*f*) Trunk haul to river or canal waterheads with subsequent delivery by road.

This indicates the field in which the maximum effort should be applied, and we add the following comments. Where goods can be loaded or discharged overside either without port dues or with a substantial reduction, water transport has a considerable advantage, but this may to some extent be reduced or lost where, owing to physical limitations, it is necessary to tranship goods at intermediate points into or out of smaller craft. Equally, liquids in bulk can be conveyed in large tank craft to inland depots situated on the waterside, from which they can be distributed by road.

Another field in which waterways may be said to be competitive is the transport of coal in large quantities. This applies particularly to the compartment-boat system operating in the North Eastern Division for the conveyance of coal to Goole, where it is tipped into seagoing ships by special appliances. The provision of such a system is exceedingly costly and requires heavy and regular movement of traffic and a relatively straight waterway with a minimum of locks. These conditions exist only in rare cases.

The waterways are extensively used for the conveyance of coal to electric power stations, gasworks and industrial installations. Relativity of cost has been affected by the application of a service charge by the National Coal Board which, though justified from their standpoint, has worsened the competitive position of the waterways. This has to some extent been improved by toll reductions.

The view of the British Electricity Authority is that the margin between canal and rail or road charges on the narrow and heavily-locked canals in the Midlands, with the restricted payload of the craft, is insufficient to induce the Authority to provide facilities at new power stations for the intake of coal by canal as well as by rail or road. They consider that in Lancashire, where larger craft are employed, conditions are generally more favourable, and that in Yorkshire, with barges carrying from 70 tons to 240 tons, charges are highly competitive.

Well-equipped warehouses provide an inducement for traders to use the waterways. Under Government bulk purchasing, warehouse space was extensively used, but with the freeing of commodities from control there is a tendency for them to pass in smaller consignments which cannot always be economically conveyed by waterway. This has also reduced the demand for warehouse accommodation. Competition by other forms of transport is severe, and as far as general merchandise is concerned is likely to become more so with the freeing of road transport and the growth in the number of "C" licences. Narrow canals which are capable of carrying approximately 50 tons per pair of boats are specially vulnerable to this kind of competition, particularly where the locks are of insufficient size to accommodate a pair of boats in one operation. The Grand Union route between London and Birmingham does not suffer from this disability. Above all, there is the need for overcoming acute difficulties in manning craft, which were frequently emphasised in the course of our investigation.

After careful consideration we have placed the waterways in three categories, according to their economic prospects : waterways to be developed, waterways to be retained, and waterways having insufficient commercial prospects to justify their retention for navigation.

Group I. Waterways to be developed : Total mileage, 336 ; Aire and Calder Navigation (including Ouse Lower Improvement) ; Gloucester and Berkeley Canal and the River Severn ; Grand Union Canal (Regent's Canal Dock and Brentford-Berkhamsted) ; Sheffield and South Yorkshire Navigation ; River Lee (below Enfield Lock) ; River Trent ; River Weaver.

These waterways carry substantial traffic and offer scope for commercial development. They should be improved by the elimination, where necessary, of accumulated arrears of maintenance, by dredging, bank protection and other improvements, and by provision of suitable handling and terminal facilities. It must, however, be appreciated that such work will involve heavy expenditure, but in our view, where economic justification exists, such expenditure should be undertaken.

Group II. Waterways to be retained : Total mileage, 994 ; Ashby Canal (used section) ; Birmingham Canal Navigations ; Calder and Hebble Navigation ; Coventry Canal ; Fossdyke Canal ; Grand Union Canal (above Berkhamsted) ; Kennet and Avon Canal (River Avon section) ; Kensington Canal ; Leeds and Liverpool Canal ; Oxford Canal (northern section) ; River Lee (above Enfield Lock) and River Stort ; St. Helens Canal ; Shropshire Union Canal (Main Line) ; Staffordshire and Worcestershire Canal ; Stourbridge and Stourbridge Extension Canals ; Stratford-on-Avon Canal (northern section) ; Trent and Mersey Canal ; Worcester and Birmingham Canal ; Ure Navigation.

The waterways in this group appear, under existing conditions, to be worth retaining for transport, either by reason of the tonnage of traffic upon them or because they form part of a through route. They should be maintained for the present to an adequate standard of efficiency. Every encouragement should be given to the development of traffic. If it becomes apparent that the retention for transport of any of these waterways is no longer justified, they should be transferred to the next category.

Group III. Waterways having insufficient commercial prospects to justify their retention for navigation : Total mileage, 771.

We received representations emphasising the importance of retaining such waterways for the purposes of water supply, land drainage and the disposal of effluents. Other possible uses are for pleasure boating and fishing, and several waterways constitute valuable amenities. The existence of these ancillary uses has in the past proved an obstacle to physical abandonment, and, as we have explained, many hundred miles of waterways are now being maintained by the Commission at heavy cost for purposes wholly unconnected with transport.

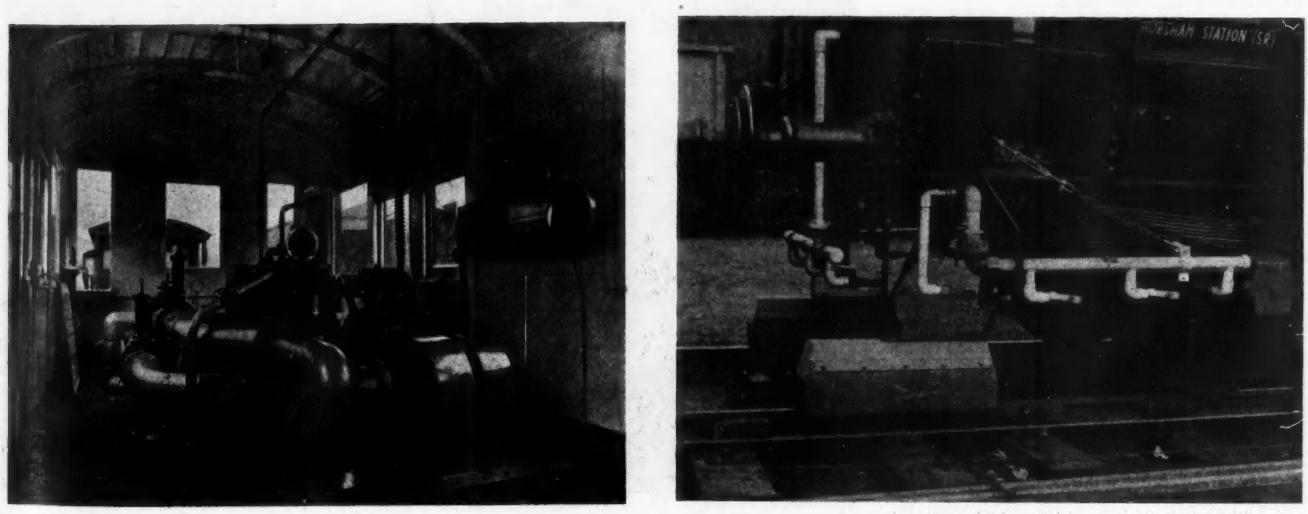
The future of these waterways was considered some years ago by the land drainage legislation sub-committee of the Central Advisory Water Committee. In their report, published in 1951, they state that River Boards are best fitted, from the point of view of both functions and constitution, to deal with the problem. They make several recommendations with a view to facilitating transfer to such boards. It is important that an early decision should be reached by the Government on these matters.

Weed-Killing Train

THE practice of destroying weeds on rail track by spraying liquid weed-killer from specially equipped trains has long been followed in this country, and in recent years a steadily increasing length of track has been treated in this way. In 1954 some 11,000 tons of liquid weed-killer were used by British Railways, and about 30,000 miles of track were sprayed. For this work most of the regions maintain their own equipment, but on the Eastern and the North-Eastern Regions it is carried out by a special train supplied by the Chipman Chemical Company, Ltd. This company manufactures the "Atlacide" weed-killing liquid, which is used on all the main lines in this country.

Recently the company designed and equipped a new spray train to the requirements of Mr. A. K. Terris, the chief civil engineer, Eastern Region of British Railways. Last week we were given the opportunity to inspect the new train which is starting a spraying programme covering 2000 miles of track on the Eastern Region and 660 miles on the North-Eastern Region. The train consists of a machinery and equipment vehicle, a messing and crew accommodation van, and six tank cars.

The 32ft long machinery and equipment vehicle is divided into two compartments, the larger one being used for the pumping and spraying equipment, and the smaller one for a workshop and stores. The pumping and spraying equipment compartment can be seen in a photograph we reproduce. The main pump is a 4in rotary "Drum" pump, which is driven through a friction clutch and intermediate pulley shaft by vee belts from a pulley on the vehicle axle. Weed-killing fluid is drawn by this pump from the tank wagons and sprayed on to the track



Machinery compartment of spraying vehicle and (right) spraying manifolds with side manifold retracted

through eleven nozzles. Three of the nozzles project down from a fixed manifold at the back of the vehicle and spray liquid on the centre of the track. Four nozzles are mounted on boom manifolds swung out at right angles at each side of the vehicle to spray the sides of the track. These side manifolds are pivoted and by means of hand levers they can be swung in against the side of the vehicle by operators in the compartment above, when passing obstructions at the side of the track. The pump has a designed capacity of 8400 g.p.m. at 410 r.p.m. and against a total head of 30 lb per square inch. The nozzles are spaced to spray weed-killer solution over an approximate width of 15ft at a rate of about 280 gallons per mile.

As the pump is equally effective in each direction of rotation a valve has been fitted in the suction and delivery lines to permit a reversal of flow, so that spraying can be carried out with the vehicle travelling in either direction. Each nozzle manifold is fitted with a separate shut-off valve so that only the required area of track is sprayed as the train passes. Pressure relief valves are fitted in the suction and delivery lines to prevent damage should the clutch driving the pump be inadvertently left in with the nozzle manifold valves closed.

A 5½ h.p. petrol engine in the compartment drives a shaft with clutch connections to a twin-cylinder vertical air compressor and a 1in "Megator" pump. The compressor charges an air receiver coupled by air lines to each of the rail tank wagons. The pump is used for spraying purposes in yards and sidings when the train is stationary and where it is impracticable to use the main pump. It draws weed-killer solution from the 4in feed to the main pump and through ¼in hoses delivers to spraying lances covering an area within a radius of 120ft of the vehicle. A 2in portable petrol engine-driven pump is carried for transferring the liquid concentrate from supply tank wagons to the train tank vehicles.

The six tank wagons are each fitted with three-way bottom outlet cocks to a main run of pipe leading to the spraying vehicle, and by the setting of these cocks liquid can be drawn from any one or all of the tanks as required. As already mentioned, a supply of compressed air is provided to each tank, and this air is used for mixing the concentrate and water prior to starting a spraying run. The air at 75 lb per square inch is forced into the liquid through a length of perforated pipe about 4in above the bottom of the tank and running along its full length.

A messing and crew accommodation van adjoining the spraying vehicle is fitted up with four sleeping bunks, a lavatory, a dining room, and a kitchen complete with a gas cooker, refrigerator and sink. The normal crew is four in number and comprises one operator in charge, a mate, a fitter and a railway man familiar with the district in which the train is operating. The first three mentioned crew are all railway employees permanently appointed to the train for the spraying programme.

In the normal filling routine the supply tanks of concentrated weed-killing solution are assembled alongside the spray train tanks and about 625 gallons of concentrate is pumped into each tank. If the train is under a water tower each tank in turn is then filled to the correct dilution rate, i.e. 3 parts water to 1 of concentrate. The air control valve on the tank is then opened and the compressed air discharged through the tank's contents. After the second or third "blow," a specific gravity reading is taken at the bottom, centre and top of the fluid. When the readings are even at a prescribed S.G. the mixing process is complete.

Under favourable conditions, where there is a well-sited water tower and a locomotive available for moving the train, the whole operation can be completed in one and a half hours.

The total capacity of the train is 15,000 gallons and this is sufficient to give a full-width spray over approximately 55 miles of track on one fill. The spraying is normally carried out with the train moving at 20 m.p.h. It is stated to be possible to spray approximately 100 miles of full-width track in one working day with this train.

Two Horizontal Oil Engines for Rail and Road Transport

ALMOST three years ago, we visited the works of Henry Meadows, Ltd., Fallings Park, Wolverhampton, to inspect the progress made in the general reorganisation of the factory and the resiting of machines. This work was planned to conform with the production flow schemes designed to effect economies to offset rising costs, and was generally described in THE ENGINEER of September 26, 1952. Last week we paid a return visit to the factory with the main object of seeing the two horizontal oil engines which the company has added to its production range to serve an even wider market. Both the new units have been developed to meet the specific requirements of the users of this form of motive power and with the co-operation of the manufacturers of railcars and coach builders. However, the engines are horizontal versions of the company's Mark 970 and Mark 330 vertical units, so that many components are common and there is little basic change between the two versions. Despite this, both engines have spent eighteen months on the test bed undergoing exhaustive trials under conditions simulating those encountered in service.

MARK 970 RAIL CAR ENGINE

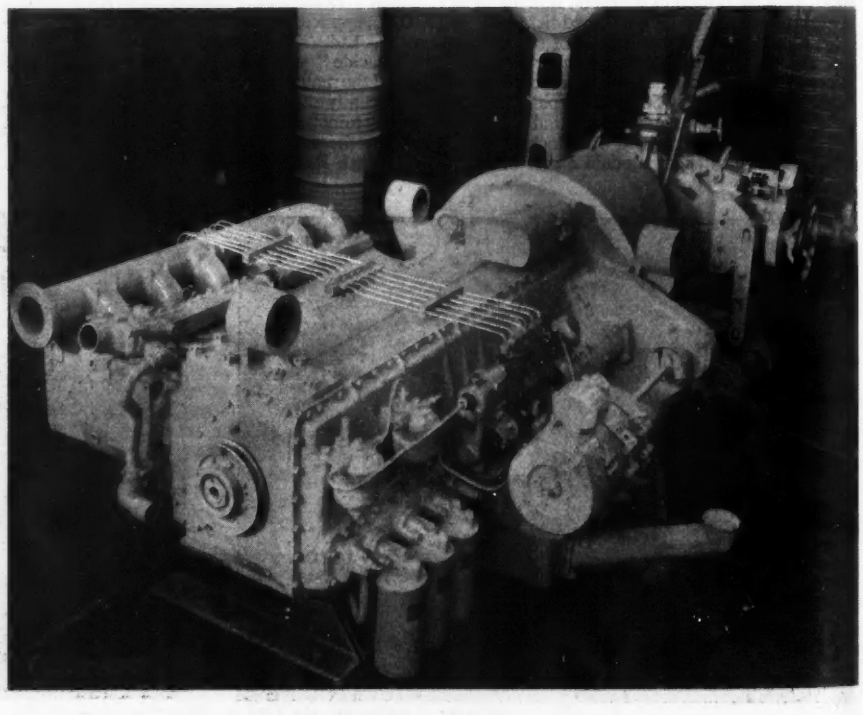
The call for maximum passenger capacity and unrestricted passageways has resulted in the need to fit engines below floor level and the consequent development of horizontal power units. To the demands of this particular market, the company has produced a horizontal version of its "970" engine, which is a six-cylinder, in-line, four-stroke, direct-injection, cold-starting, water-cooled compression ignition unit, having a bore and stroke of 150mm and a capacity of 15·9 litres. The horizontal model is available as normally aspirated or in supercharged form, the engines being designated Mark 6 HDT 970 and 6 HDTS 970, respectively. The normally aspirated model develops 165 b.h.p. at 1800 r.p.m., has a maximum brake mean effective pressure of 83 lb per square inch, a compression ratio of 16 : 1, a maximum fuel consumption of 0·40 lb/b.h.p./hr, and a weight of 3808 lb. When fitted with an exhaust gas turbo-charger, the engine has the following corresponding technical data: 240 b.h.p. at 1800 r.p.m.; brake mean effective pressure 120 lb per square inch; compression ratio 15 : 1; fuel consumption 0·358 lb/b.h.p./hr and weighs 4108 lb. Our illustration shows the normally aspirated model and the accompanying graph includes curves giving performance data while the test results are embodied in tabular form.

TABLE I—*Test Results: Exp. 6 HDT 970*

Bar. 29·7. Amb. 66 deg. Fah.

R.p.m.	B.h.p.	lb./b.h.p./hr.	lb./sq. in b.m.e.p.	lb./ft torque	Exhaust temp., deg. Cent.
1800	184	0·401	83	539	530
1600	176	0·376	89·5	581	525
1500	168·5	0·372	91·5	594	515
1400	161	0·375	93·5	607	510
1200	139·5	0·369	94·5	614	480
1000	113	0·362	92	596	440
900	99·5	0·365	90	585	415
800	87·5	0·367	89	578	400
600	63·4	0·366	86	555	380

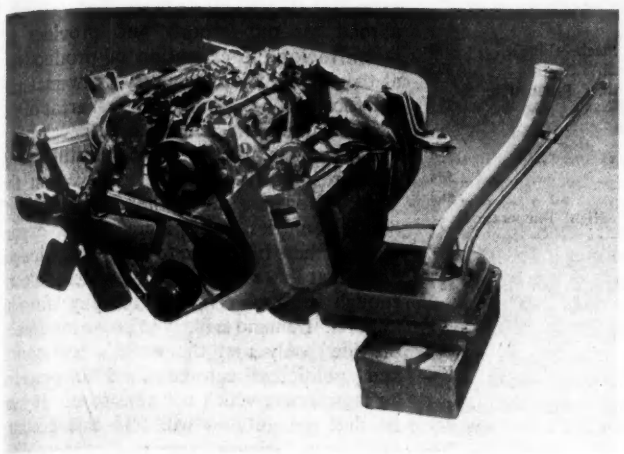
The engine is strongly built, having a crankcase of high-grade cast iron and two cast iron cylinder blocks, each of three bores, fitted with wet cylinder liners centrifugally cast in high-duty alloy iron. Two high-grade cast iron detachable cylinder heads are fitted, there being provision for two inlet and two exhaust valves per cylinder, together with renewable valve seat inserts. The valves are operated through bucket pattern tappets, tubular push rods, and primary and secondary rockers from a camshaft, which is machined from a steel stamping and carried in seven bearings. To reduce the inertia effects of the valve and rocker gear, each push rod is loaded into its mating bucket tappet by a compression spring. One of the inlet valves is plain and the other is masked, an arrangement which has been adopted as a result of development work showing that more efficient combustion was attained thereby. Forged aluminium alloy pistons, having three compression and two scraper rings are employed, and the connecting-rods, which are H-section steel stampings, are drilled for lubricating the small end bush and have thin shell copper-lead big end bearings. The crankshaft, which has main bearings of 4·25in dia-



Six-cylinder, four-stroke oil engine for rail cars

meter and crankpins of 4in diameter is carried in seven bearings.

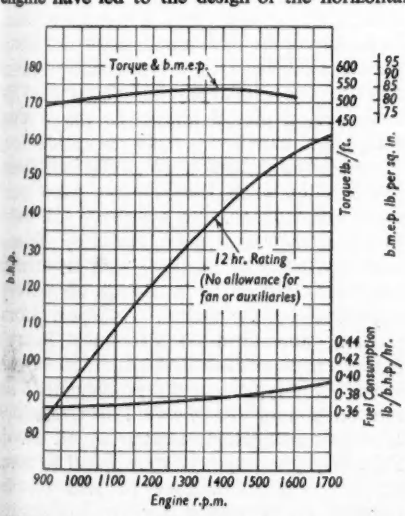
Fuel is pressure fed from the tank by a feed pump to an injection pump and then solidly injected through long-stem multi-hole nozzles into the cylinder. In the fuel system are triple-bowl paper element filters and the centrifugal governor is mounted on the fuel pump, all being manufactured by C.A.V., Ltd. There is a wet sump with detachable pannier incorporated in the engine and a gear pattern pump, driven from the main timing chain, delivers oil to the crankshaft bearings, while an auxiliary pump supplies the camshaft, valve rockers and gear drives. All the oil passes through full flow filters, mounted on the crankcase end cover, and a gear-driven centrifugal pump circulates the cooling water which flows longitudinally and transversely to give even cooling of the cylinders. For starting there is a 24V dynamo, which is gear-driven from the main timing gears, and two 24V electric motors. In the supercharged model the exhaust gases are led through two cast iron manifolds to the turbo-charger which is mounted at the front of the engine and is water cooled from the engine system.



Four-cylinder, four-stroke oil engine for road transport

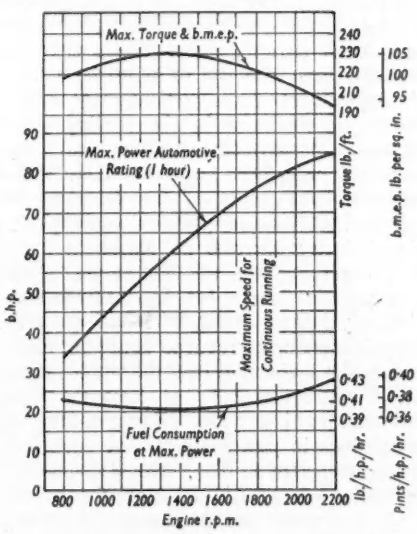
Mark 330 Horizontal Automotive Engine

Somewhat similar reasons to those which prompted the development of the "970" engine have led to the design of the horizontal automotive engine which can be mounted under the floor of a vehicle and so provide maximum passenger or load-carrying capacity. This unit, Mark 4 HDC 330, is a horizontal edition of the 4 DC 330 engine, which was fully described in The Engineer of September 15, 1950. The general appearance of the new unit can be seen in our photograph, reproduced herewith, and the engine is designed to develop a maximum of 85 b.h.p. at 2200 r.p.m. This four stroke, direct-injection, water cooled, compression ignition engine has four cylinders of 120mm bore and stroke, a capacity of 5·43 litres, a compression ratio of 16 : 1, a maximum brake mean effective pressure of 105 lb per square inch, a maximum torque of 230 lb per foot at 1350 r.p.m., and weighs, with flywheel, about 1100lb. The main technical data is shown graphically on the performance chart, which we reproduce, and from which it can be noted that the fuel consumption is 0·43 lb per brake horsepower per hour at 2200 r.p.m. Table II gives the results on the test bed.



Performance chart 6HDT 970 normally aspirated engine

A high-grade monobloc iron casting forms the crankcase and cylinder block, which is fitted with centrifugally cast wet liners of high-grade iron alloy and the two detachable cylinder heads, each covering two bores, are of high-grade cast iron. There is one inlet and one exhaust valve per cylinder and for both there are renewable valve seat inserts centrifugally cast in high chromium iron alloy. The valves are operated by rocker gear actuated by cast iron bucket tappets and short push rods from a pressure lubricated camshaft having five bearings running in white metal bushes. The pistons, die cast in aluminium alloy, have three compression rings, the top one of which is chromium faced, and two scraper rings. The connecting-rods, which are high tensile steel stampings, have copper-lead-lined steel bushes forming the small end bearing and precision pattern big end bearings of thin shell steel-backed copper-lead-lined and lead-indium treated. Five similar bearings carry the four-throw hardened crankshaft. In the vertical engine a harmonic balancing system was incorporated, consisting of two contra-rotating counter-balanced shafts, driven from the crankshaft, which gave freedom from secondary out-of-balance forces. It is of interest to note that it has been found to be unnecessary to employ these harmonic balance shafts in the horizontal model.



Performance chart 4HDC 330 engine

The fuel pump is gear-driven and there is a Meadows centrifugal variable speed governor and also an automatic advance mechanism which advances the point of fuel injection as the speed of the engine increases. A Hobourn-Eaton pump provides forced feed lubrication throughout the engine, an adequate quantity of lubricant being carried in a wet sump. For circulating the cooling water there is a centrifugal pump mounted at the front end of the engine and belt-driven from a pulley on the crankshaft, the same belt driving the battery-charging dynamo. The temperature of the water is controlled by a bellows pattern thermostat and the design of the pump allows for a six-bladed fan to be mounted on the pump spindle. There is a 24V motor for starting purposes.

Table II—*Test Results : 4 HDC 330*

Baro. 29·04. Amb. 72 deg. Fah.

R.p.m.	B.h.p.	lb/b.h.p./hr.	lb/sq. in b.m.e.p.	lb/ft. torque
2200	85	0·41	92·5	203
2000	81	0·4	97	213
1800	75	0·39	100	219
1600	68·5	0·388	103	226
1400	61·5	0·385	104	228
1200	52·5	0·385	105	230
1000	43	0·385	103	219

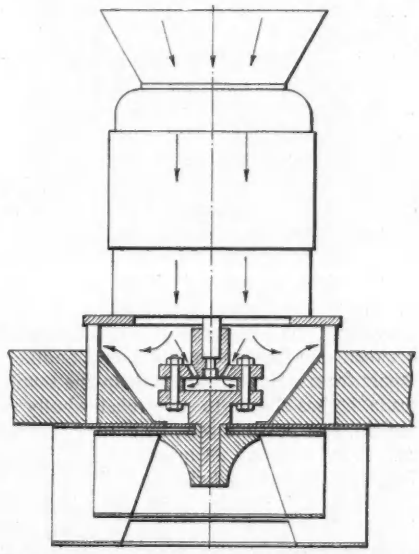
Coupling for Hot Air Fans

Particulars have been received from the Spooner Dryer and Engineering Company, Ltd., Moorland Engineering Works, Ilkley, Yorks, of a coupling developed by the firm to prevent the transmission of heat from fans circulating hot air along the shaft to the driving motor. In the baking equipment made by this firm, fans are used to circulate air at temperatures of 600 deg. Fah. or more, and it became necessary to prevent heat being transmitted to the motor bearings.

The arrangement of the new form of coupling can be seen in the drawing reproduced below. In this coupling flanges on the fan rotor shaft and the motor shaft are spaced apart by distance pieces, and rigidly connected together by fitted bolts. Holes drilled through the flange on the motor shaft admit air into the space between the flanges and the distance pieces provide a form of blade to draw in a current of cooling air. This current of air not only cools the flanges, but also the distance pieces and coupling bolts to provide an effective form of heat insulation between the fan runner and the motor.

The makers state that the accuracy of the couplings is such that the balance even at high speeds is as good as with a solid coupling. Preliminary tests showed that a shaft, without its runner, brought up to a temperature showing red heat could be run continuously without the bearings showing signs of heat.

In actual practice, the firm uses this arrangement for the circulation of high temperature air in a gas or oil heater in an indirect heating system. Here, the temperature of the products of combustion in circulation is 800 deg. Fah., and with the fan running continuously, the temperature in the motor bearings does not rise to a temperature very much above 100 deg. Fah., or approximately 35 deg. above the surrounding air.



Arrangement of heat insulating coupling between hot air fan rotor shaft and driving motor

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A PLEASANT SURPRISE

How remarkable can be the fluctuations of human fortunes ! Six months ago, looking at booming trade figures, a continuing, though small, monthly increase in the gold reserves, and taxation returns that already promised a substantial Budget surplus, it was easy to anticipate that the spring would see the load of taxation substantially eased. Yet now that spring has come and the Budget has been opened we are all surprised, pleased, and a little disturbed to discover that there has been any relief of taxation at all ! For ever since the New Year opened the gloomier economic prophets have been prognosticating fearful things unless home demand for imports and for this country's own products could be held down and exports be expanded ; and suggesting that the terms of trade which have already moved against this country may move still further in the same adverse direction. But Mr. Butler, true to the form he has shown in opening every Budget since he became Chancellor, has proved more sanguine and confident than many of the prophets. May he be once again proved right by events ! With an election imminent there was not much room for manœuvre and none for niceties of adjustment between one form of taxation and another. Apart from doing a little to help the textile trade, he has chosen to give relief wholly in the simplest possible way, by cutting income tax, thus benefiting all taxpayers from great industrial firms to individuals.

Of course, it remains to be seen whether it is Mr. Butler who is right in easing the taxation burden to the tune of one-half of his calculated Budget surplus or whether the pessimism of economists will be justified by events. The true situation is not likely to be revealed until the autumn, by which time the recent increase of Bank rate here and certain measures adopted by other countries of the sterling area will have begun to exert their full effect. The chances seem equally balanced. Mr. Butler bases his confidence upon some factors that are sure enough, some that are more debatable. If exports are to expand, for example, so as to balance out the turn of the terms of trade against this country, the world situation must favour expansion. On the whole it does, as recent activities of the Organisation for European Economic Co-operation and recent decisions under the General Agreement upon Tariffs and Trade have indicated. Again there has recently been a revival of industrial activity in the United States, a particularly promising factor as weakness in the sterling area's balance of payments position may very possibly be traced, in part at least, to a delayed consequence of the American recession. At home, at least within the engineering industry, there is no reason at all to suppose that there will not be that " real increase in investment in manufacturing industry " upon which Mr. Butler counts. Nor is there much room to doubt his assessment that investment over the whole field in 1955 will increase by at least the same amount as last year. Furthermore, tax remissions in past Budgets have each been accompanied by a rise in personal savings and a further rise following upon the present reduction of tax can therefore be confidently predicted. But is it reasonable to estimate that " the increase in home demand should be appreciably less than it has been in the last two years " ? Certainly it is not comforting to realise that whereas between 1953 and 1954 output per man over the whole economy rose by about 2½ per cent wage rates increased by over 4 per cent. For there is evidence there of an inflation that it should be the business of a Budget to attempt to check.

Yet even if upon the short-term the outlook appears unsettled, on the longer term it is bright enough. It is perhaps upon those longer-term favourable factors that Mr. Butler is counting. There is certainly a continuing tendency towards inflation in this country. It seems to prove impossible to hold the expansion of incomes down to the rate at which productivity rises. But that is not a situation confined to Britain. The phenomenon is worldwide. Again, though the terms of trade have moved in the last twelve months against this country, there is little need for depression about a movement that builds up purchasing power abroad for our exports and provides an incentive for the expansion of productivity at the sources of this country's raw material and food supplies. Above all, vast areas of the earth's surface still remain to be developed ; and enormous numbers of people still live at standards far below those achieved in the West. However much the competition of other countries may increase in export markets there is no need to fear, on the longer term, that this country will be unable to earn enough through exports to pay for its imports. Demand is likely to prove insatiable, provided only that the world's economists and politicians can continue to preserve an atmosphere which will release it. It may be that the autumn will find this country once more facing balance of payments difficulties. It is indeed quite probable that a fear of that possibility, combined with an appreciation of the unwisdom of holding an election under such circumstances led the Government to choose May rather than October to go to the polls. But it is hard to believe that the difficulty need be either so severe or so prolonged as those this nation has experienced at other times since the war. Indeed, Mr. Butler's confidence may well prove justified. The difficulty may not arise at all.

INLAND WATERWAYS

A hundred years is considered a good age for a civil engineering work. Many do not last as long ; they may become worn out, or the need for them may change. But others last for a century and may serve usefully for a much longer time. It is unusual however, to find a series of works that have lingered on, neither fully used nor quite moribund, for well over a hundred years, as many canals have done, after an initial period of intensive use. The canal system of this country was largely built between 1760 and 1830, a period known as the " canal era." The canals originally competed very successfully with horse traffic, using indifferent roads. But when the railways were built the canals declined. Yet they were still used, to a greater or less extent, and they still are used. What is to be done with them now has been studied by a Board of Survey, appointed by the British Transport Commission, and abstracts from the Board's report are reproduced on page 558 of this issue. It is typical of the problem that the introduction of *Bradshaw's* 1904 *Handbook* of inland navigation, written by H. R. de Salis fifty years ago, is still topical to some extent. " Whatever may be said on the question of the unfair starving and stifling of canals by railways," he says, " there is no doubt that in the first place the canals had largely to thank themselves for it. In many cases the canal companies forced the railways to purchase or lease their undertakings at substantial prices before constructing their lines. Canals in their day reached a far greater pitch of prosperity than the railways

have ever attained to, but they suffered fatally, and do so now, from the want of any serious movement towards their becoming a united system of communication. Each navigation was constructed purely as a local concern, and the gauge of locks and depth of water was generally decided by local circumstances or the fancy of the constructors without any regard for uniformity. The same ideas of exclusiveness appear to have become perpetuated in the system of canal management."

Throughout the last fifty years, committees and commissions of one form or another have, at intervals, prepared reports on the canal system, and recommended what should be done to rescue the canals from neglect and decay, and there has been public anxiety over the state of the canals for a century. But practically nothing has been done during that time. The present Board of Survey thus had a dismal history to look back on, but was able to record a slight improvement over the past few years. Traffic on the canals had dropped to 10,000,000 tons a year when the British Transport Commission took them over in 1948, but had risen to 13,000,000 tons by 1953. The financial loss was reduced to £102,060 in 1953, on a turnover of about £2,000,000, but the loss did not include any contribution, the report states, "to central charges, the main item of which is capital which stands in the book at £22,370,000." The Board believes that the measures it proposes, although not claimed to be a final solution, will enable the canals and inland waterways to be used more and to greater advantage in the transport system. Its cardinal recommendation is that the British Transport Commission should concentrate its activities on 336 miles of canals where the traffic is sufficient to justify modernisation and improvement generally. A further 994 miles, it recommends, should be retained, and adequately maintained, for the present. The remaining 771 miles should be discarded altogether. But how or to whom are they to be discarded ? These 771 miles of canals have uses "wholly unconnected with transport," but involve a loss of about £200,000 a year to the Commission. There was thus the unenviable problem facing the Board of suggesting, with due diplomacy, some other department, which might take responsibility for them. Fortunately, a previous governmental committee had bravely suggested that the River Boards were the most suitable recipients for this responsibility, and so the Board has drawn attention to that view. It will be interesting in due course to learn what the River Boards feel about the suggestion.

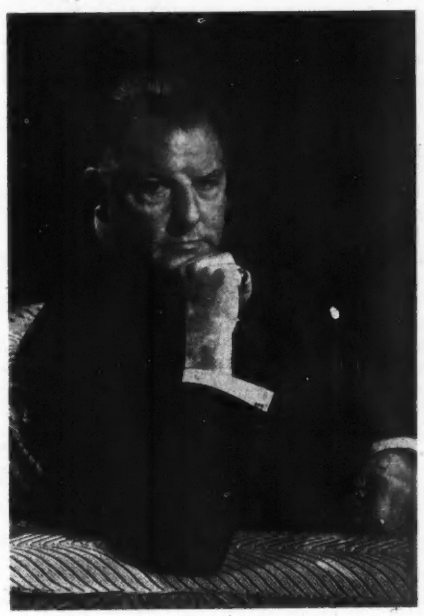
Considering the problem solely from the British Transport Commission's point of view, it is doubtful whether the Board could have made any other suggestions about the canals which would have been more practical and realistic than those contained in the report. There are, however, wider questions involved than those of transport alone. Many industrial establishments depend upon canals for water supply. There is the amenity aspect. There is a public health aspect should a canal be allowed to become quite derelict. Moreover, little technical thought has been given over the past decade or so, during a time of rapid technical advance in other fields, to the modern possibilities of inland waterways. It is not at all easy to say what an up-to-date canal system—designed in all its aspects to modern standards—would be able to achieve. The only example in the Board's report of the application of modern ideas appears to be that of the compartment boat system at Goole, the advantages and limitations of which are clearly stated. New schemes for canals are, practically speaking, unheard of. The only recent contribution we can bring to mind is Mr. J. F. Pownall's proposal for a "grand contour canal." Briefly, he envisages a canal system without locks, at 310ft above sea level, serving a large area of England ; the canal would be 100ft wide by 17ft deep and connected by locks at various places with existing navigational systems. The proposals include an idea analogous to the multi-purpose development of river valleys, now so widely known and practised : the grand contour canal, would act as an aqueduct for water supply as well as for navigation, and the proposed Cotswold and Buckingham arms of the canal would enable Thames flood waters to be stored in the Great Oolite beds (see *The Dock and Harbour Authority*, November, 1951). Whether or not Mr. Pownall's scheme is practicable is probably dependent upon this idea of linking canals with water conservation. It certainly seems possible—despite our only too plentiful rainfall !—that water supplies may become a critical factor in the country's future develoment, both agriculturally and industrially. Any use of canals, new or old, which facilitated water supply might therefore be important. But that is a consideration which it would be unfair to expect the British Transport Commission to bear in mind. The Commission's job is to organise transport, not water conservation. Yet this multiple use of a canal system would also affect the economics of transport on it, for, quite obviously, water supply and flood control, when applicable, could meet part of the cost. Perhaps the present time would be opportune for the Institution of Civil Engineers to organise a symposium for the exchange of technical views on these various problems of the derelict canals, and of what might reasonably be expected from a modern canal system, under to-day's conditions and with the background of heavy capital expenditure envisaged for roads and railways over the next ten or twenty years. Why not ? After all, a paper to be presented before that Institution on April 26th, assumes that the railways are also derelict and ought to be converted into roads ! But we confess that it seems to us improbable at this date that anyone would be bold enough to venture upon the construction of new canals even if, as a consequence, older canals were thereby likely to be re-invigorated as a means of transport. Yet without new construction it is obvious enough that the majority of the canals of this country can never again be expected to provide an economic means of transport. Nor are they well adapted for water conservation or distribution. The Commission would like to "write off" a third of them immediately and another 50 per cent more, very probably, in the not distant future. But they cannot be written off by a stroke of the pen ! If the Commission abandons them some other body must become responsible, even if it is responsible only for filling some of them in. It is a sad story. We may well ponder Mr. de Salis's remarks. Had there been a better standardisation of lock gauges and canal depths the work of the thousands of "navvies" who constructed the canals—and later found work in constructing railways—would not have set a problem of disposal that in our day we find it so difficult to solve. Will posterity have to draw similar conclusions, we wonder, about some of the engineering achievements of this century ?

Obituary

MAJOR F. B. HALFORD, C.B.E., F.R.Ae.S.

It is with regret that we record the death of the distinguished engine designer, Major Frank Bernard Halford, which occurred suddenly at his home in Sandy Lane, Northwood, Middlesex, on Saturday, April 16th. Major Halford, who was sixty-one, had been chairman and technical director of the de Havilland Engine Company since its formation in 1944, and was a director of the de Havilland Aircraft Company, Ltd.

He was born at Nottingham and after attending Felsted School, proceeded to



F. B. Halford

Nottingham University. Just before the first world war he became a flying instructor with the Bristol School of Flying at Brooklands. Following a short period as engine examiner for the A.I.D. in the first year of that war, he served for the remainder in the Royal Flying Corps and the Royal Air Force, being later lent, in 1919, to William Beardmore and Co., Ltd., as engine designer. The Beardmore-Halford-Pullinger (B.H.P.) six-cylinder engine was developed during this period. He became associated with Ricardo and Co. later that year, first representing them in America and later as an engine designer in London. In 1923 he set up on his own as design consultant and from 1924 to 1927 was engine designer to A.D.C. Aircraft, Ltd., and consultant engineer to Vickers, Ltd. In 1927, however, he joined the design staff of de Havilland Company,

where he stayed for eight years until joining D. Napier and Son, Ltd., as technical director. During these various appointments he was responsible for a whole family of outstanding petrol engines, including the "Airdisco," "Cirrus," "Gipsy" and "Nimbus" and later the Napier "H" block engines, "Rapier," "Dagger" and "Sabre." In 1944 the de Havilland Engine Company was formed as a separate company under his direction and the manufacture of the "Goblin" and "Ghost" centrifugal turbo-jet engines, and the design of the supersonic jet engine, the "Gyron" established. Major Halford was appointed C.B.E. for his contributions to aeronautics in 1948. In 1927 he was elected a Fellow of the Royal Aeronautical Society, a member of council in 1949, and president in 1951.

A. E. MARGOLIS

We record with regret the death of Mr. A. E. Margolis, which occurred at his home at 45, Bramham Gardens, London, S.W.5, on Wednesday, April 13th. Mr. Margolis, who was well known as a specialist on district heating, had been on the staff of Messrs. Kennedy and Donkin, consulting engineers, of Westminster, since December, 1941. Before coming to this country in the 1930s, Mr. Margolis had spent many years in the installation of district heating plants in Germany, France and Czechoslovakia. For eight years, from 1921 to 1929, he was manager of the District Heating Company, Hamburg, and for the next four years he was director of the district heating department of the Hamburg Electricity Company. The results achieved by Mr. Margolis in the course of his career have been regularly recorded and commented upon in the many papers on district heating which he presented to engineering institutions and congresses in this country and abroad. He received the silver medal of the Institution of Heating and Ventilating Engineers in 1935 for his paper entitled "Experiences with District Heating in Europe and the U.S.A." In 1953 Mr. Margolis presented a paper, in collaboration with Mr. Bryan Donkin and Mr. C. G. Carrothers, to the Institution of Civil Engineers describing the Pimlico district heating undertaking. An abstract of it appeared in THE ENGINEER of December 25, 1953.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

REPORTS FROM THE FOOTPLATE

SIR,—In reply to some points raised by Mr. Fullagar, I have to say that :

(1) I would not question a report of an operation at King's Cross merely because I had never seen a similar one there.

(2) The front windows on "A.4's" cannot be opened inwards.

(3) The driver concerned did not ask anyone about water level.

W. A. TUPLIN,
Professor of Applied Mechanics.

Sheffield,
April 18th.

POLYTROPIC EFFICIENCY

SIR,—Much of the confusion attached to the term "polytropic efficiency" the author believes may be attributed to a failure to distinguish between a reversible and an irreversible polytropic process. It is clear from many texts that isentropic changes and "frictional heat" are woven together to form the basis of the theory upon which the polytropic efficiency is established. Such an approach is unnecessary as there is no connection between the polytropic and isentropic processes. The appearance of the isentropic index γ, in the expression for the polytropic efficiency is not due to the influence of some isentropic process, but to the fact that $\gamma/(\gamma-1)=c_p/R$. Accordingly, the following treatment is not based on the properties of the isentropic process and the reader is asked to concentrate on the polytropic process.

In the adiabatic expansion or compression of a fluid, which may be gas or air, in a multi-stage unit the effect of turbulence and other thermodynamic losses is to cause the path of the state change on the temperature-entropy diagram to be one of continuously increasing entropy. It is found that such a state change may be represented very closely by an equation of the form $pv^n=c$, relating the pressure and volume, where n is the polytropic index. In an actual change, the polytropic law $pv^n=c$ must be an irreversible process. Consequently, if the path of the actual process could be plotted on the $p-v$ and $T-S$ diagrams the areas on the diagrams would not represent work or heat exchanged with the surroundings, It so happens that the expression $pv^n=c$ represents the law of a reversible polytropic which follows the same path as the irreversible polytropic.

Let us suppose we base the efficiency of the compression or expansion in an irreversible polytropic change on the reversible polytropic which has the same form of $p-v$ or $T-S$ relation, i.e. usually $pv^n=c$. Consider an elemental step, dp, on the polytropic. If the change were to take place reversibly the ideal work quantity would be $\frac{vdp}{J}$. Admittedly, the reversible work $\frac{vdp}{J}$ is accompanied by a heat flow, but all that is being suggested here is that if the path were traversed reversibly the work would be $\frac{vdp}{J}$.

Let η_{ip} be the polytropic or "small stage" efficiency such that η_{ip} is defined as the ratio $\frac{\text{ideal work}}{\text{actual work}}$ (in compression) and $\frac{\text{actual work}}{\text{ideal work}}$ (in expansion). Now the actual work is c_pdT or the change in enthalpy in an adiabatic process.

Hence we may write

$$\eta_{ip}=\frac{vdp}{Jc_pdT} \text{ in compression,}$$

or

$$\eta_{ip}=\frac{Jc_pdT}{vdp} \text{ in expansion.}$$

Continuing with the case for expansion—compression being the reciprocal—we have

$$\frac{1}{\eta_{ip}} . J . c_p . dT=vdp,$$

or

$$\frac{1}{\eta_{ip}} . \frac{Jc_p}{R} . \frac{dT}{T}=\frac{dp}{p}, \text{ since } v=\frac{RT}{p},$$

i.e.

$$\frac{1}{\eta_{ip}} . \frac{\gamma}{\gamma-1} . \frac{dT}{T}=\frac{dp}{p}, \text{ where } \frac{Jc_p}{R}=\gamma/(\gamma-1).$$

From the polytropic relation $pv^n=c$ it follows that

$$\frac{dT}{T}=\frac{n-1}{n} . \frac{dp}{p}.$$

Hence,

$$\frac{1}{\eta_{ip}} . \frac{\gamma}{\gamma-1} \frac{n-1}{n}=1,$$

i.e.

$$\eta_{ip} \text{ (expansion)}=\frac{\gamma}{\gamma-1} . \frac{n-1}{n}.$$

It follows that η_{ip} in compression is given by

$$\eta_{ip}=\frac{\gamma-1}{\gamma} . \frac{n}{n-1}.$$

The above proof is straightforward and the definition of η_{ip} relates immediately pressures and temperatures on the polytropic without recourse to friction work, friction heat, &c. It might be suggested that the polytropic efficiency is more academic in nature than the isentropic efficiency and that the efficiency is merely an artifice for relating γ to n.

E. A. BRUGES
The University,
Glasgow.

RAILWAYS AND INDUSTRY

SIR,—In your leading article on April 1st, you stated that it would be very wrong if the British Transport Commission should decide to build diesel locomotives. Such a statement should be explained in some detail. If you mean that the railways should not build complete diesel locomotives, including the oil engines and the transmission system, there may be some justification for the statement, but there can be no reason against the railways buying the power unit and designing and building the remainder of the locomotive around it.

In Britain there is only one contractor who has built complete diesel locomotives of high power, so in that respect the other locomotive manufacturers are not better placed than British Railways, who have already gained experience in designing, building and operating main line locomotives of over 1600 h.p. The building of diesel-electric shunting locomotives with purchased power units is now an established practice on British Railways and is providing work to compensate for some of the lost steam locomotive building. In the writer's opinion there exists on British Railways sufficient technical staff to build up a separate section for the design of power and transmission units if the British Transport Commission should decide on that policy, but even if that is not adopted, it will be possible to repeat and improve on what has been done already during the last ten years.

P. W. BOLLEN
Folkestone, Kent.

[Our correspondent has overlooked our leading article of March 11th, in which the situation was more fully discussed.—ED., THE E.]

SANDWICH STRUCTURES FOR HIGH TEMPERATURE SERVICE

SIR,—With reference to the account you published in your American Section on April 1st, of my company's development of high temperature sandwich material—"Solite"—I would be very much obliged if you could make it clear that the material is not yet commercially available, nor are we yet ready to negotiate licences. I ask this in view of the great interest currently taken in such materials in general, and our "Solite" in particular.

W. E. P. JOHNSON,
European Manager, Solar Aircraft Company
Piccadilly,
London, W.1.
April 12th.

Books Received

Electric Power Transmission. By J. Zaborszky and J. W. Rittenhouse. London : Thames and Hudson, Ltd., 244, High Holborn, W.C.1. Price 70s.

Industrial Dust. Second edition. By P. Drinker and T. Hatch. London : McGraw-Hill Publishing Company, Ltd., McGraw-Hill House, 95, Farringdon Street, E.C.4. Price 71s. 6d.

Solution of Problems in Surveying and Field Astronomy. H. W. Stephenson. London : Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, W.C.2. Price 25s.

Cycles and Performance Estimation. Volume 1 in the Gas Turbine Series. By James Hodge. London : Butterworth's Scientific Publications, Ltd., 88, Kingsway, W.C.2. Price 50s.

Steel Designer's Manual. By C. S. Gray, L. E. Kent, W. A. Mitchell and G. B. Godfrey. London : Crosby Lockwood and Son, Ltd., 26, Old Brompton Road, S.W.7. Price 50s.

Institution of Naval Architects

ANNUAL SPRING MEETING

No. III—(*Continued from page 530, April 15th*)

THE second paper read at the meeting on Tuesday morning, April 5th, under the chairmanship of Mr. R. B. Shepheard, was entitled :

NAVAL DEVELOPMENTS IN NAVAL LIFE-SAVING EQUIPMENT

By W. J. HOLT, R.C.N.C.

SYNOPSIS

Over the period of the post-war years there has been much research and experiment in the field of the life-saving equipment carried in H.M. ships. The paper touches upon the equipment used in the first and second world wars, and the lack of development and goes on to set out the main requirements for new equipment. Details are given of the results of investigations into the design of a suitable life jacket and the problems relating to life rafts, such as size, protection and insulation, inflation, boarding, drift stability and food supplies are discussed. The various tests and trials are referred to and the question of maintenance is examined together with such items as stowage and operation.

DISCUSSION

Sir Charles S. Lillicrap : I am glad that in the paper Mr. Holt has paid tribute to one of the younger members of the Naval Life Saving Committee, who did such a lot ; it is stated that he " almost literally risked his neck in efforts to achieve optimum design." It is very gratifying that this committee has now given to the seagoing public a reasonable chance of survival in case of disaster.

Some of us were harried when people went overboard and the ship was surrounded by a mass of burning oil, and were burned to death. I should like to ask the author how he thinks these rafts and such like will survive in such conditions and whether any consideration whatever was given to countering this very dreadful fire risk. I was disappointed to see that the results of sea water stills had not been promising. At the time of the inception of this committee I had hoped that we should have a successful outcome of these experiments, and I still feel that something can be done and will be done in the future.

In his concluding remarks Mr. Holt states : " To the writer of this paper it appears that the next main problem requiring thought is the organisation on board to ensure that the crew of a ship can make their way to the weather deck and thus be in position to board the rafts." Both in warships and merchant vessels, where there is such a large number of compartments, it is absolutely essential to have organisation, quick and efficient, which can get people to the positions where they can make use of the life-saving appliances provided.

Mr. J. P. Allsopp : Mr. Holt's paper does service in drawing attention to the efficiency which present-day inflatable apparatus has reached. It describes only the dinghies which are now in use in the Royal Navy and does not deal exhaustively with inflatable dinghy designs. The Royal Navy dinghy is quasi-elliptical in plan and has a single main buoyancy tube subdivided by two baffles on the minor axis.

Some designers prefer to retain the circular plan, which Mr. Holt calls the car tyre type, and some use a nearly true boat shape with soft-pointed stem and transom stern, and in some designs the subdivision of the main buoyancy is obtained by using the " double bubble " principle, i.e. two separate main tubes, one above the other. Some of each of these designs, except the boat-shaped ones, are already approved for limited use in the Merchant Navy.

Mr. Holt tells us that the R.A.F. dinghy is the root stock from which the naval dinghy is developed. Indeed, almost the whole technology of the rubberised cotton fabrics and inflation equipment is associated with the aircraft industry.

Surgeon Commander J. W. L. Crosfill, R.N.: Life saving in the shipping world has been lamentably neglected ; one could accuse the shipping world in general of gross neglect, if not of criminal negligence in the matter of life saving. The Carley float did not save anybody's life if they were on it, and it is now obsolescent. What is the value of the life raft ? The fact is that it prevents those who are in it from dying of thirst in the tropics or from exposure in cold waters. It is stated in the paper that in the life raft trials the temperature inside the tent was maintained at about 70 deg. Fah. from the body heat of the trial party. We had not a full complement, but the ventilation sleeve was opened partly and when that sleeve was closed the temperature went up to about 80 deg. Fah. People jumped into cold water at a temperature of about 40 deg. Fah. and swam to the rafts and got inside ; and a film was taken to show how they got into rafts when cold. Afterwards I thought I saw smoke coming out of the ventilator sleeve ; it was not smoke, but condensation, for it was so hot. The tests to see what happened to body temperatures were made in winter, in sub-Arctic conditions, but with one exception those inside felt warm within a quarter of an hour, metabolic heat having warmed up the air.

It was shown at Singapore that the body water lost in the tropics, provided those using the rafts carry out the drill properly, was no greater than it was in cold conditions. That is a great saving, because if a man is sweating he can lose litres of water per day, the average at Singapore being about a litre per day per man. Solar stills have been tried there, and over an eight-day period, which included cloudy and rainy weather, the yield was 750 cubic centimetres per day, while under the ideal conditions of dry and sunny weather the yield was 1200 cubic centimetres per day. There are a lot of problems not yet tackled, and one of the most serious, particularly from the merchant shipping point of view, is how to get people into the rafts. If that problem had been solved I do not think the tragedy of the " Princess Victoria " would have occurred.

Mr. J. F. Coates : A raft such as those described in the paper is primarily an insulated cocoon around its occupants, and it is important to understand what goes on in the tent. The rate at which a man can lose heat when he is wet and in an exposed atmosphere in heavy weather is very great, so that it is essential that the loss of heat should be cut down, not only by insulating the man, but by preventing evaporation as much as possible. Possibly the only way of doing that is to put the man into an atmosphere having a relative humidity of 100 per cent, because then the moisture in his clothing does not evaporate at all ; he is just as well off in wet or dry clothing, and that is perhaps one of the greatest benefits that total enclosure can give. Therefore, a life-saving appliance is deficient unless it can put a practically complete hermetically sealed canopy around its occupant.

Another reason for providing total enclosure in any lifeboat or raft is that even with the best arrangements for conveying people to it, some are bound to get wet. Some will be wet for a long time and will be severely chilled, and there is a threshold of chilling from which one can recover provided one is warmed. If a raft has a properly sealed enclosure, it will be possible for such cases to be warmed by the body heat of their more fortunate companions.

Mr. A. P. Patterson : A certain amount of maintenance will have to be carried out on board ship. But we found that it was almost impossible to get and train people to do the work, and there was not the space aboard ship in which to lay things out. We have laid it down that when we put rafts on board ship, only minor points would be examined and the equipment should be serviced ashore by a thoroughly independent organisation, which is being formed gradually in the Service. It is working very well and has given excellent results where the equipment has not been interfered with on the ship.

Mr. Holt was a little nervous about the charging of the CO_2 bottles ; but provided the check weighing is carried out at intervals of six months there is no danger. After about forty-eight hours the amount of gas remaining in the bottle is entirely the same, and complete inflation can be achieved. The inflation times with the very early rafts have been just over a minute, and sometimes just under a minute, which is rather surprising.

With regard to ship organisation, we are preparing an instructional film which will show how to handle the rafts. The people concerned will be given the drill, and the film, which we hope will be completed some time this year, will show what they have to do when they get out of the ship. Another matter is the boarding of life rafts. It is necessary that men should be able to get into the rafts fairly quickly, and that is the reason why we went away from the " double-bubble." The twenty-man raft would have been of the " double-bubble " type, but that meant that the men would have a long way to climb out of the water. We started with a raft which weighed about 180 lb, but now the raft itself, without equipment, weighs about 240 lb. We are trying to make a rubber Rolls-Royce.

Mr. A. M. Currie : It has been mentioned that there are many reasons why equipment which is suitable for a naval vessel may not be suitable for a merchant ship. The former has a disciplined crew consisting of trained men who are in the fullest sense seamen, whereas a cargo vessel very often has only about 15 or 20 per cent of those on board who are seamen at all. For that reason we have to look upon the advent of these rafts carefully, but there is no question that the development of the inflatable raft gives in many cases a greatly improved chance of surviving.

The usefulness of the raft in a merchant ship appears to be inversely proportional to the size of the ship. In smaller ships with low freeboard which are liable to sink quickly, and which probably have rather rudimentary methods of lifeboat handling, the raft seems to offer something attractive.

About maintenance on board I have in mind a small trawler of about 100ft and would like to know what maintenance is necessary from week to week or from month to month, and can it be done on a small ship like a trawler ? If rafts are stowed in such a ship, is there reasonable assurance

that they will be in good working condition if required ? Does it take more than one or two men to carry out the routine inspection, and who does the inspection ? On that class of ship we must have something very simple to handle.

Mr. B. W. Townshend : Inflatable rafts cost more than buoyant apparatus ; maintenance and depreciation costs, I think, would be comparable provided they are properly protected. If we take into account the saving of tonnage not only of life-saving equipment, but that due to the possible reduction in the size of the ship itself, I think there is no questioning the advantage of using inflatable equipment. The value represented by the saving in training men to replace those who would otherwise be lost is also a very important point. The British Air-Sea Rescue Service saved 6800 air crew and about 5000 others during the last war, mainly by inflatable dinghies. The saving in training costs alone probably amounted to more than £40,000,000 ; quite apart from the humanitarian aspect, that factor has to be taken into account when considering the better prospects of saving life at sea.

The one-man dinghies used by the R.A.F., the Royal Naval Air Arm, are made from two-ply rubberised cotton frabric weighing about 8 oz. per square yard. Such a dinghy weighs rather less than 6 lb complete with weather cover and hood and it has kept men alive when afloat for up to eleven days. Many crews have survived very much longer ; the longest known was that of an American crew who were thirty-four days afloat in the Pacific.

Mr. W. H. Thomas : It is a major tragedy that, whilst ships have developed so much in recent years, little or nothing has been done to ensure survival of the men who sail in them. Little more has been provided in various cases than the floating log, to which the sailor might lash himself. It is only natural that we all think of the human aspect of life-saving ; but there is another aspect which is important in wartime, and that is to shield trained men from exposure when a ship is sunk, for the cost in time and money involved in replacing those men may well be critical. The R.A.F. realised the importance of this during the war. A comprehensive rescue organisation for ships as well as aircraft, I feel, is now due.

Mr. Holt, replying to the discussion, said : Sir Charles Lillicrap has raised the question of escape from ships surrounded by burning oil. It is difficult to arrive at a solution for that contingency ; but I think the Ministry of Transport are looking into the design of what may be called an insulated boat. I am inclined to think that we shall have to accept what the gods send in special circumstances. I do not think it is a general thing when a ship goes down that it is surrounded by burning oil, but it may happen.

On the question of the application to merchant ships, I feel that for little ships such as trawlers there is a lot to be said for life rafts. It is a case of small ships and small boats. I think the life raft is quite a good thing ; it does not weigh much and it would insulate survivors from a trawler.

From the point of view of the big passenger ship the problem is to get people down the side of the ship to the rafts on the water. They would have a very good chance of survival in boats in calm weather, and people would perhaps prefer to be in boats, but for very bad weather I think we might be driven to use life rafts, which would have a much better chance of survival than would boats.

(To be concluded)

Physical Society Exhibition

No. I

THE thirty-ninth exhibition of scientific instruments and apparatus organised by the Physical Society is being held next week at the New Hall of the Royal Horticultural Society. For the first time in its history, therefore, the exhibition will be staged outside the Imperial College of Science and Technology, which has housed all the previous exhibitions of the Society. For some years past the space made available by the hospitality of the Imperial College authorities has been inadequate for the needs of the exhibition. At the same time the College has been finding it increasingly difficult to satisfy its own space requirements. From this point of view, at least, the break with tradition should benefit both the exhibition and the College.

In this year's exhibition, for example, there will be 139 stands, whereas last year there were only 103 stands ; last year's exhibition catalogue, however, contained a section devoted to twenty-two " non-exhibitors," in which descriptions were given of equipment " which would have been exhibited if space had been available."

The exhibition will be opened on Monday, April 25th, at 10.30 a.m. by Professor R. Whiddington, F.R.S., chairman of the Physical Society's exhibition committee. Until 2 p.m. it will be open only to the Press and Fellows of the Society. Thereafter admission will be by ticket only, until 8 p.m. on Monday, from 10 a.m. to 8 p.m. on Tuesday, and Wednesday, and from 10 a.m. to 5 p.m. on Friday, April 29th.

During the period of the exhibition three discourses or demonstration lectures will be given in the lecture theatre (second floor) as follows :—Monday, April 25th, 6.15–7 p.m., " The Free Electron as a Tool in Scientific Research," by Mr. M. E. Haine, of Associated Electrical Industries Research Laboratories, Aldermaston, Berks ; Tuesday, April 26th, 6.15–7 p.m., " Memory Systems in the Brain," by Professor J. Z. Young, F.R.S., of University College, London ; and Wednesday, April 27th, 6.15–7 p.m., " Recent Developments in Luminescence and its Applications," by Dr. G. F. J. Garlick, of the University of Birmingham.

Once again visitors to the exhibition will be able to inspect the entries for the Society's craftsmanship and draughtsmanship exhibition ; these entries will be displayed in the vestibule of the New Hall.

Some of the instruments and apparatus which can be seen at the exhibition next week are described briefly below.

Metropolitan-Vickers Electrical Company Ltd.

Advances in electron microscopy will be among the developments shown by Metropolitan-Vickers Electrical Company, Ltd., Trafford Park, Manchester, 17. This company will show its " EM3A " electron microscope (Fig. 1), which incorporates recent modifications and differs from the " EM3 " equipment shown in previous exhibitions in the following particulars. Facilities for reflection microscopy are built into the new microscope. The traverse and tilting mechanism for the electron gun is so designed that a tilt of 10 deg. is obtainable in one direction for surface reflection working, this tilting action being continuous from the upright position.

A new kind of electron gun is fitted and a number of modifications have been adopted which improve the stability of the electron beam. The gun anode is integral with the top face of the condenser lens as on the " EM3 " microscope, but, in addition, an anode aperture plate is fitted which can be moved laterally by means of two screwed pushrods operated through the vacuum wall. This adjustment allows the diverging electrostatic lens at the anode aperture to be used to correct misalignment of the electron beam due to random lateral displacement of the filament tip. The gun can therefore be kept operating at maximum brightness, a facility which is useful for successful reflection working.

To assist in setting up specimens for reflection microscopy an auxiliary window has been added to the specimen chamber and a pre-specimen aperture is also provided. The objective lens fitted to this microscope is of new design and incorporates water-cooled windings. An adjustable objective aperture assembly is built into this lens ; it takes the form of a rod with the aperture disc in a holder on the end, passing radially into the space between the pole pieces through the non-magnetic spacer. The position of this rod is controlled from outside by two micrometer screws. It can be withdrawn from the beam when no aperture is required, and the whole

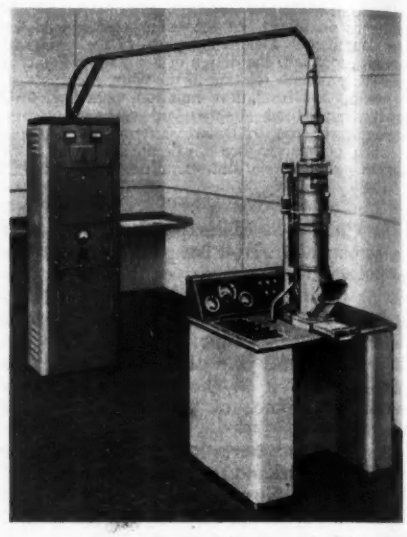


Fig. 1—Electron microscope with universal head for reflection microscopy and micro-diffraction—Metropolitan-Vickers

assembly can be removed from the lens for changing the apertures without dismantling the microscope column. Water cooling is only necessary when the lens is being operated at 4000 to 6000 ampere-turns to obtain the highest possible resolution. An astigmatism corrector is fitted to the objective lens.

One detail which has been developed but will not be included in the instrument as exhibited is a door-mounted reflection specimen stage, which can be substituted for the normal specimen stage door. This reflection stage is designed to handle specimens up to $\frac{1}{2}$in diameter and $\frac{1}{16}$in thickness. The specimen can be traversed by external controls in two directions in a plane normal to the main axis. It can also be tilted through an angle of approximately 10 deg. to obtain the desired angle of incidence for the reflected beam, and it can be rotated on its own axis through 360 deg.

The company will also show a vapour phase chromatograph—an instrument (Fig. 2) which provides a means for analysing and separating gases and volatile liquids. The sample is injected on to the top of inert packing contained in a glass column, the packing used is " Keiselguhr " impregnated with a high boiling point solvent, usually dinonyl phthalate. A continuous flow of nitrogen passes through the column and carries the sample along as a vapour. The components of the mixture pass through the column at varying rates. The time taken for each component to pass through the column is a characteristic of that component for a particular set of operating conditions and depends on such factors as the vapour pressure and solubility in the stationary liquid phase (high boiling point solvent). That component which is least soluble and of the highest vapour pressure emerges first. The relative concentration of each component in the nitrogen stream is indicated by a thermal conductivity cell in the outlet line. This concentration is

recorded by a pen recorder as a series of peaks of conductivity as a function of time.

The glass column has a spiral path length of 6ft and can be heated to any temperature up to 150 deg. Cent. If it is desired to substitute a different liquid phase to improve separation this change can be quickly effected, as the column is easily removed. Liquid samples can be introduced by hypodermic syringe, the normal sample size being 0·05 c.c. Gases are introduced by opening a valve and forcing in a predetermined amount of sample. The chromatograph may be adapted for process monitoring work by the provision of an automatic valve and control. The flow of nitrogen is controlled by needle valves and is indicated by a variable flow meter. Inlet and outlet pressures are indicated by dial type pressure gauges and a vacuum pump is used when it is necessary to operate with an outlet pressure of less than 760mm Hg. Provision is made for temperature measurement and control.

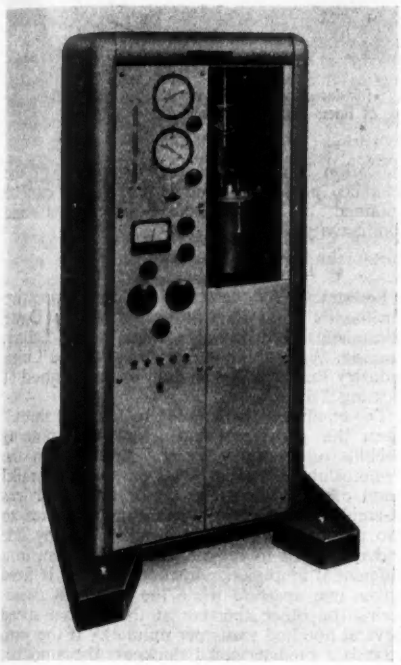


Fig. 2—Vapour-phase chromatograph for the analysis and separation of gases and volatile liquids—Metropolitan-Vickers

Good separations can be obtained with many different kinds of compounds—for example, hydrocarbons, alcohols, aldehydes and ketones. To carry out quantitative analyses it is necessary to calibrate the instrument with the individual components or, for greater accuracy, with a synthetic blend. Qualitative analysis is assisted by the fact that for a particular series of organic compounds there is usually a simple relationship between the time of emergence and the chain length.

A mains supply of 250V, 50 c/s, is required and the maximum power requirement is 1kW.

Another interesting exhibit will be a laboratory prototype of a double focusing mass spectrometer which is intended for the general analysis of solids, both for impurity assay work and for the determination of major constituents.

In this spectrometer positive ions, representative of the composition of the sample being analysed, are produced when a high-voltage spark occurs between electrodes of the sample material located close together in the vacuum system. These ions are accelerated by a potential of 20kV and pass through an electrostatic analyser followed by a magnetic analyser, designed to the geometry of Mattauch, so that the ions are focused according to their mass as a series of lines in a single plane. The mean radius of the electrostatic analyser is 6in and thus for a source slit of 0·005in the theoretical resolving power of the instrument is 600.

The intensity of the ion beams can be recorded either photographically or electrically. With the full accelerating voltage of 20kV, ions of mass 2 to 400 can be focused on to a collector by varying the magnetic field and their intensity measured electrically in the usual way. Proportionately higher masses can be focused by decreasing the ion accelerating voltage. A separate collector is provided for monitoring the total ion beam intensity, one function of which is to facilitate the setting up of the sample electrodes.

The instrument is arranged for photographic recording so that a mass range of 1 : 20 can be covered in a single exposure of the photographic plate (i.e. mass 20–400 at 20kV with the full magnetic field). A rack mechanism allows ten exposures to be taken on the same plate, without loss of vacuum, and an electronic timer is incorporated in the spark circuit so that by employing different exposure times it is possible to analyse for trace impurities in solids. Up to five samples can be changed in the source for calibration or other purposes, without loss of vacuum.

Amongst the experimental apparatus on show is an infra-red radiation pyrometer. This instrument was designed primarily for use in studying temperature distribution in the region of the tool tip during a metal cutting operation and is capable of other applications where surface temperatures over very small areas are to be measured. Basically the instrument has three component parts—an optical unit, an infra-red sensitive detector and an amplifier. The optical unit is a conventional reflecting system consisting of two spherical mirrors which focus the infra-red radiation from the hot surface on to an opaque screen. The detector, a B.T.H. type "C" lead-sulphide cell, is fitted behind the screen and the amount of radiation falling on it is determined by a "pin-hole," the diameter of which can be varied. The radiation beam is "chopped" at 100 c/s and the alternating signal from the cell is fed into a frequency selective amplifier which has a narrow bandwidth at 100 c/s.

Kelvin and Hughes, Ltd.

Two new developments associated with the Kelvin Hughes ultrasonic flaw detector are being shown for the first time. They consist of a compensated automatic scanning and recording device which produces a paper record of the examination of any specimen, and a depth gauge, whereby the thickness of metal plate, accessible on one side only, can be determined.

It may be recalled that the principle of operation of the Kelvin Hughes flaw detector is that it sends out an ultra-high-frequency pulse from a quartz crystal probe at a frequency from roughly 0·5 Mc/s to 5·0 Mc/s, according to the material being tested. The pulse from the transmitting probe travels through the test piece to the opposite side and returns to the receiving probe. When the pulse leaves the transmitting probe a small peak is traced on the cathode-ray indicator. Its return from the opposite face is also traced on the indicator so that the distance between the two traces on the c.r.t. time-base is directly proportional to the thickness of the test piece. Any flaw between the face on which the probes rest and the opposite face causes some of the transmitted energy to be returned to the receiving probe and this "echo" is traced on the tube. The size of this trace is normally an indication of the size of the flaw.

The automatic scanning and recording equipment has been developed for use in cases where a permanent record of the ultrasonic examination is required; it was originally designed for the examination of long welds in large pressure vessels. It consists, briefly, of two main parts. The first is a modified form of combined vertical probe which houses the transmitter and receiver elements in a single head; this head is traversed along a gantry to scan the required route at a fixed speed. The second part is a pen recorder, which shows a deflection when a flaw is detected, the amplitude of the deflection being proportional to the size of the flaw and the position being determined from the recorder paper. Surface friction is minimised by mounting the probe on special skids, permitting high-speed scanning without damage to the probe. Acoustic contact is maintained by feeding water from a self-primed circuit (operated by a motor-driven pump) into the gap between probe and surface.

Automatic compensation is provided for variations in acoustic contact between probe and the specimen and other variables affecting sensitivity. A flaw-detection warning system gives a visual or audible signal when flaw echoes above a predetermined magnitude are detected. A circuit failure alarm system is included to give a visual or audible signal when the acoustic contact or circuit efficiency falls below a predetermined standard. This signal may be supplemented by an automatic "cut-out" arrangement.

The new depth gauge embodies a reference unit consisting of a column filled with liquid in which are immersed two quartz crystals, one transmitting and one receiving. The time for a pulse of ultrasonic energy to travel from one crystal to the other in the liquid is known and the distance between the crystals can be altered to increase or decrease this travel time. This reference unit produces a trace on the cathode ray tube and provides a calibration whereby the distance between the transmitted and received pulses from the probe gives the thickness of the metal.

Elliott Brothers (London), Ltd.

A three-channel automatic balancing strain gauge bridge which was designed mainly for wind tunnel strain measurements, and is used in the R.A.E. and N.A.E. supersonic wind tunnels, will be shown by Elliott Brothers (London), Ltd., Century Works, Lewisham, London, S.E.13.

The strain gauge bridge excitation is at 600 c/s and the out-of-balance signal from the bridge is fed into an amplifier consisting of two channels, one feeding the balance meter and the other feeding the servo motor fields in the bridge units. The meter channel consists of two stages of a.c. amplification followed by a phase-sensitive rectifier circuit, the first stage of the a.c. amplification being common to both meter and servo amplifier. The servo amplifier has a total of three stages of a.c. amplification followed by a phase-sensitive rectifier circuit, and a further two stages of d.c. amplification for the operation of the motor fields. The bridge is stated to have a sensitivity better than 0·00001 per cent strain and an amplifier input sensitivity better than 3×10^{-7} V.

On the same stand visitors will be able to see a dynamic flow meter which was designed to facilitate study of the true input-output functions of hydraulic servo-valve units, without noticeable interactions due to the intrusion of the measuring element. It is virtually unidirectional and will therefore show only the "positive" part (for example) of any given alternating flow waveform. But since variable orifice control is also unidirectional, the flowmeter can therefore provide almost all the information needed about the flow output of such valves. Its sensitivity is limited mainly by the performance of the capacitance pick-off. Usually the highest gain setting is used, consistent with freedom from zero errors due to d.c. drift and change of dielectric constant with temperature. Thus the stiffness of the spring elements in the flowmeter is changed for each individual application; this is a simple operation. By merely changing the pick-off gain setting, the full-scale reading of the model shown may be varied between 5 and 50 g per sec. Departure from linearity is no more than 2 per cent of full-scale deflection in any given range. The frequency response is also dependent on permissible gain which is limited by temperature variation of dielectric constant of the fluid. Fidelity in the useful range of 0 to 20 c/s is adequate for servo work.

The same company will also show a small general-purpose analogue computer (GPAC) which is built from a number of standard units (such as amplifiers, function generators, &c.) similar to those used in "TRIDAC," the large computer which was recently built by the company at the R.A.E. The small computer to be exhibited consists of a single self-contained cabinet capable of accommodating twenty drift-corrected standard units. Problem setting is done on interchangeable plug-in panels, an arrangement whereby new problems can be prepared while other problems are being solved. In particular the computer is suitable for the simulation of aircraft control system calculations.

Another computer development that will be

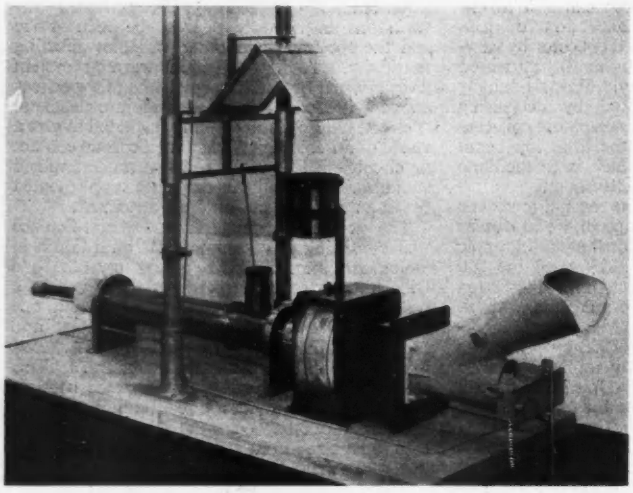


Fig. 3—Ultra high speed camera—Mullard

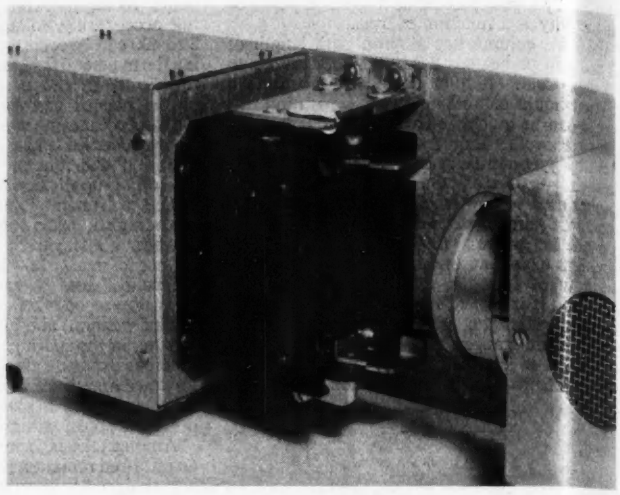


Fig. 4—" Photoslubber " for detecting slubs or oversize threads in the weaving of linen—Dawe Instruments

seen on the same stand is that of digital storage on a magnetic tape consisting of 35mm film.

MULLARD, LTD.

Progress in ultra-high-speed photography will be demonstrated (Fig. 3) by Mullard, Ltd., Century House, Shaftesbury Avenue, London, W.C.2. The developments shown are based on established techniques of the use of image converter tubes as the shutters of ultra-high-speed cameras. The image of the object to be photographed is focused on the sensitive photo-cathode of the tube. When operating voltages are applied, a duplicate image appears at the opposite end of the tube. To photograph fast transient phenomena, the tube is switched on by voltage pulses synchronised with the phenomena, the actual photographic record being made by an ordinary camera at the viewing end of the tube.

In the past, circuit limitations have fixed the lower limit of exposure at about 30×10^{-9} seconds, whereas the use of a coaxial pulsing system (as demonstrated) enables the exposure time to be reduced to one-tenth of its value, that is to 3×10^{-9} seconds.

It will be shown that a voltage pulse produced by a very fast spark discharge travels down a coaxial line to trigger the tube. At the same time, the light generated by the spark is guided by mirrors to the photo-cathode of the image tube. When the light path is lengthened by moving the mirrors, a point is reached where the image of the spark on the viewing screen disappears, because the light arrives at the photo-cathode after the voltage pulse which triggers the tube has died away. By adjusting the length of the light path, the various stages in the formation of the spark can be seen, and the effective exposure may be reduced to about 3×10^{-9} seconds, the picture on the tube being visible to the eye and recordable by film.

A section of the stand will be devoted to the use of transistors and demonstrations will be given of transistors applied to electronic switching, for example, in computers and telephone exchanges. For this kind of duty transistors offer potential advantages because of their low heat dissipation compared with that of the thermionic valve. Three demonstrations will be given. The first illustrates a decade counter with four decades having a resolution time of 50 micro-seconds. The second is a shifting register which will operate at any repetition frequency up to 100 kc/s. The third is a demonstration of the use of transistor gates to operate a matrix store made up of " Ferroxcube " rings having rectangular hysteresis loops.

Another demonstration will show the use of a film scanning particle counter and sizer, with the help of an instrument which scans photo-micrographs of small particles and counts the number of particles of a given size group within the field of view. Total counts as well as size distributions can be obtained. A cathode-ray tube flying-spot scanner is employed to examine the film sample, point by point via an optical system. A line-to-line memory ensures that each particle is counted only once. Sizing is accomplished by a subsidiary exploration. Electron-micrographs, photo-micrographs and photographs of dispersions can be analysed. The system is suitable for extension to direct microscopic examination of specimens.

A. E. CAWKELL

An ultrasonic instrument for the non-destructive testing of concrete will be shown by A. E. Cawkell, 6 and 7, Victory Arcade, Southall, Middlesex. This instrument, which is in production, is based on a design originated by the Road Research Laboratory and it incorporates improvements suggested by field experience. An earlier instrument has been used, for example, to confirm the compressive stress of precast concrete structural units for school buildings and to check the strength of precast beams.

The method used is to calculate the longitudinal wave velocity of an ultrasonic pulse (transmitted and received through the specimen by barium titanate transducers) by measuring the transmission time of the pulse. Time measurement is effected by examining a cathode-ray tube trace which sweeps in synchronism with the transmitted pulse and shows the transmitted and received pulses. The time scale is given by 50 and 10 micro-second marker pips, together with a 0 to 10 micro-second interpolating control, using an expanded sweep-measuring technique.

The accuracy of the instrument is said to be better than $\pm 0{\cdot}5$ per cent, the calibration being controlled by checking the markers periodically against a crystal gate. With a range from near zero to 600 micro-seconds, the instrument is suitable for concrete thickness up to 8ft. The apparatus is housed in a case 21in high by 18in wide by 22½in deep.

SOLARTRON ELECTRONIC GROUP, LTD.

Another example of non-destructive testing will be demonstrated by the Solartron Electronic Group, Ltd., Thames Ditton, Surrey, using research apparatus developed for testing non-ferrous metals by eddy current methods.

The sample metal rod, or tube, is passed through a search head consisting of two coils in series on a former. Eddy currents are induced in the search coils which form two arms of a bridge and the out-of-balance voltage is amplified in the laboratory amplifier " AWS.51A " (which can be made selective) and is indicated by a phase-sensitive voltmeter " VP250." Any flaws or changes in conductivity or dimensions will alter the eddy current configurations and produce a complex change in the balance of the search coils : this change will be analysed into vector components by the phase sensitive voltmeter. One advantage of this method of presentation over that of resultant out-of-balance indication is that, by suitable rotation of the reference phases, a separate indication can be obtained of simultaneous dimensional and conductivity changes.

DAWE INSTRUMENTS, LTD.

Equipment for detecting yarn of excessive thickness (" slubs ") will be shown by Dawe Instruments, Ltd., 99, Uxbridge Road, Ealing, London, W.5, who collaborated with the Linen Industry Research Association in this method of locating " slubs."

The equipment is designed to locate " slubs " when the yarn is wound from the spinning bobbins on to the weaving cones. When the " photoslubber " (Fig. 4) is in use a parallel beam of light from a projector lamp and lens assembly is passed through two apertures to two photocells which are installed side by side and connected to form a balanced system in a differential amplifier. A standard yarn is fixed across one aperture while the test yarn passes across the other aperture at the normal speed (several hundred yards per minute). If the yarn exceeds a predetermined thickness the amplifier output lights an indicator lamp and actuates a thyratron which has an electromagnetically-operated cutter in the anode circuit. The cut in the yarn is made before the " slub " reaches the cutter and the " slub " can then be removed by the operator.

(To be continued)

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1

SHEET METAL PATTERN DEVELOPMENT. PART 2 : INCIDENCE OF THE NEUTRAL LINE.

No. 1549, Pt. 2 : 1955. Price 5s. This is a companion to Part 1 of this standard, which was published in 1949. This part gives recommendations for the determination of the position of the neutral line for use with mild steel of from 14 B.G. to 20 B.G., and duralumin and half-hard aluminium of from 14 S.W.G. to 20 S.W.G., where the inside radius of the bend lies between a figure equal to the thickness of the metal and a figure equal to four times the thickness of the metal. Examples of calculations are given and supporting evidence is contained in appendices.

DRUMS FOR COVERED WINDING WIRES AND STRIPS

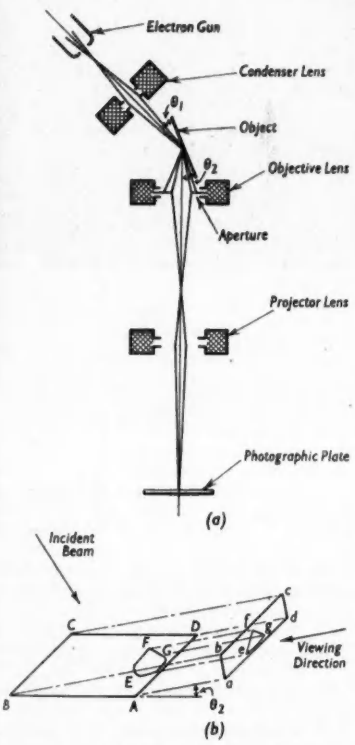
No. 2565 : 1955. Price 2s.—This standard for drums for covered winding wires and strips for electrical purposes includes four different flange diameters, each with two traverse dimensions. The standard gives full details of dimensions and specifies the essential requirements for materials, construction, reeling, wrapping, labelling and marking. It also introduces a system of reference numbers for the identification of the drums and introduces the specification of a peg hole in each drum to take a braking device.

Surface Examination by Reflection Electron Microscopy*

By J. S. HALLIDAY, Ph.D.†

In reflection electron microscopy, the surface is viewed very obliquely and the surface protuberances are seen in profile. It is shown that the method may be used for the quantitative study of surface finish. The method is particularly suitable for the examination of surfaces on which the irregularities are small and ground, lapped, finely abraded and polished surfaces can conveniently be studied. Micrographs of various metals show that ground surfaces of comparable roughness may have different textures, and these differences appear to be related to the mechanical properties of the metals. The range of surface finish which can be examined is illustrated by micrographs of electropolished aluminium which, over large areas, is flat to about 0·1 deg., and on which the highest asperity is 0·4 micro-inch, and of ground hardened tool steel, with asperities up to 70 micro-inches high and sloping at 30 deg. to the general surface. The method is suitable for the examination of surface damage by wear processes, and the surface damage on copper after passage of a steel slider is illustrated. Finally, the advantages of reflection electron microscopy over other methods of surface examination are discussed.

RECENTLY there has been renewed interest in the method of reflection electron microscopy as a means of examining surfaces. It was in 1933 that Ruska made the original attempt to form images of metal surfaces by directing a beam of electrons at the surface and focusing those which were scattered. Although the resolution was poor it was later improved by von Borries and Janzen (1941) to about 1 micro-inch, which is as good as that generally obtained to-day. However, with the development of the replica techniques for the examination of surfaces with the electron microscope, the method fell into disuse and only very recently has it been revived, see for example, Cosslett and Jones (1953), Fert and Saporte (1952), Haine and Hirst (1953), Menter (1952). It now appears that for the examination of certain types of surface the method has advantages over others already established, and it seems particularly suitable for the study of the surface texture of metals finished by the better engineering methods. In this paper, an examination of surfaces prepared by grinding, lapping and abrading is described, and it is shown that quantative measurements can be made of the asperity sizes and of their maximum angle of slope with respect to the mean surface level. An example of the use of the method as a research tool in mechanical engineering is also given.



(*a*) Schematic representation.

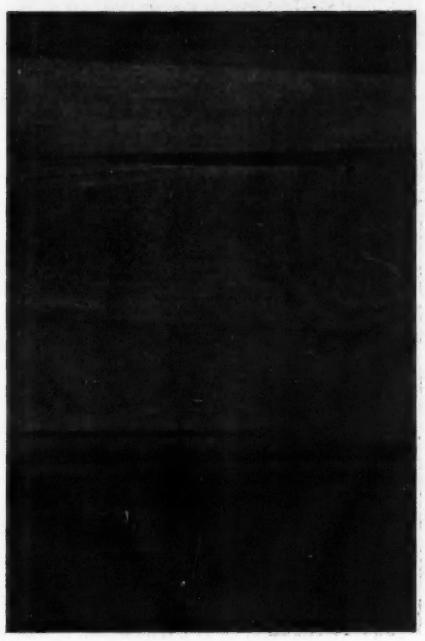
(*b*) Variation of magnification in the micrographs (schematic).

Fig. 1—The reflection electron microscope

APPARATUS

The electron microscope used is as described by Haine and Hirst (1953), so only a brief summary of the basic principles will be made. A schematic diagram of the electron optical system is given in Fig. 1.

A fine beam of 50keV electrons, from an electron gun, is focused on to the surface of the specimen. The angle between this electron beam and the surface, θ_1, can be adjusted by tilting the electron gun and condenser lens assembly. The electrons are scattered at the metal surface and, using an aperture, those scattered through any chosen angle can be selected. These scattered or " reflected " electrons are focused on to a photographic plate by the objective and projector lenses. If $\theta_1+\theta_2$ is the total angle of scattering selected, then θ_1 may be termed the angle of illumination and θ_2 the angle of viewing.



$\theta_1=0·1$ deg. ; $\theta_2=3·9$ deg.

Fig. 2—Aluminium, electropolished

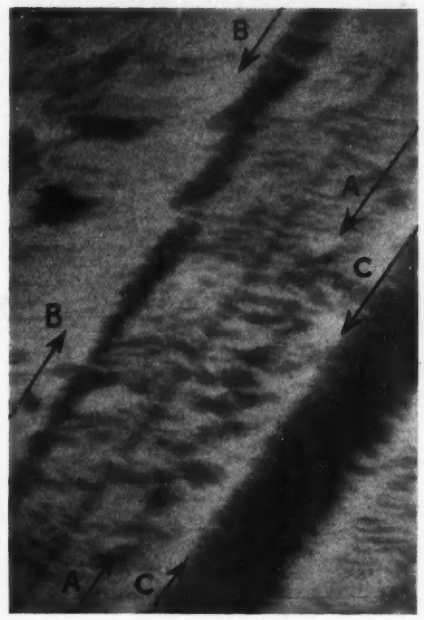
INTERPRETATION OF THE REFLECTION MICROGRAPHS

All details on the surface of the specimen which lie in planes normal to the scattered electron beam will have the same magnification $m_\perp$ in the image. Since θ_2 cannot exceed $4\frac{1}{2}$ deg. with the present apparatus, the profiles of asperities on the surface, drawn across the electron beam, can be regarded as being in planes normal to the electron beam, and therefore as appearing undistorted in the image, for example Fig. 1(*b*). Fig. 1(*b*) shows diagrammatically the image of a flat surface *ABCD*, having one conical asperity *EFG* ($m_\perp=1$). The image of the profile *EFG*, which is across the electron beam, is shown at *efg*, and is undistorted. However, details lying within the plane of the surface suffer considerable distortions. The magnification in a direction across the beam is $m_\perp$, but at an angle ϕ to this direction, the magnification m_ϕ is given by

$$m_\phi=m_\perp(\sin^2\phi\sin^2\theta_2+\cos^2\phi)^{\frac{1}{2}} \quad . \quad . \quad (1)$$

Thus images of specimen details parallel to the electron beam are magnified only $m_\perp \sin\theta_2$ times, and when $\theta_2=4$ deg., then $m_\phi=90$ deg.$=m_\perp/14·3$. For example, in Fig. 1(*b*), the length of the specimen *AB* is shortened in the image to *ab*, whereas its width is unchanged.

Haine and Hirst (1953) have discussed in detail the mechanism of contrast formation in reflection electron micrographs and its dependence on θ_1 and θ_2, so only a brief description is given here. Ignoring any effect of the angles θ_1 and θ_2 on the scattered intensities, the changes in contrast due to asperities are as follows. When the surface slopes so that the local value of θ_2 is increased, then the reflected intensity is lower and, conversely, when θ_2 is locally decreased, then the reflected intensity is higher. Thus the side of a hollow nearest the observer appears bright after the darker region due to the hollow, but the bright top of a hill is followed by a darker region due to the hill side. Thus hills and hollows can be distinguished by the variations in con-



$\theta_1=4$ deg. ; $\theta_2=4$ deg.

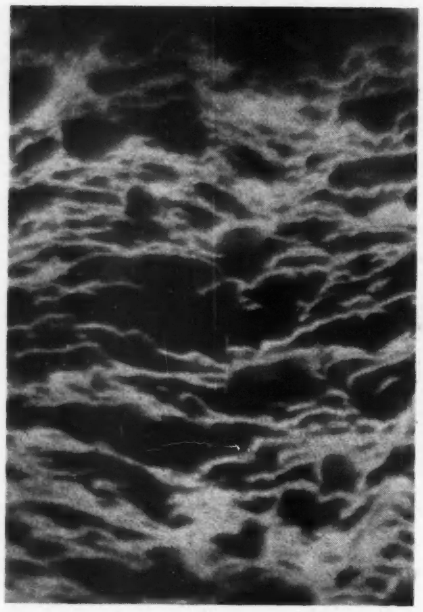
Fig. 3—Tool-steel, hardened and ground

$\theta_1=4$ deg. ; $\theta_2=4$ deg.

Fig. 4—Copper, ground

* Institution of Mechanical Engineers, April 15th. Extract.

† Physicist, Surface Physics Section, Research Laboratory, Associated Electrical Industries, Ltd., Aldermaston, Berks.



100μin.

θ_1=4 deg. ; θ_2=4 deg.

Fig. 5—Mild steel, ground

trast, examples of such variations are clearly visible in Fig. 2.

If there are asperities on the surface having sides inclined at angles greater than θ_1, the incident beam will cast shadows ; the asperity height h can be calculated from the length of the shadow image in the direction of the incident beam l, using the formula (Haine and Hirst, 1953)

$$h=\frac{l}{m_\perp}\cdot\frac{\sin\theta_1}{\sin(\theta_1+\theta_2)} \quad . \quad . \quad . \quad . \quad (2)$$

Measurement of the shadows can provide a much more sensitive means for determining asperity heights than the direct measurement of surface profiles. Thus, for a surface which just casts shadows at a very small angle of illumination, for example, θ_1=0·1 deg., and when using a viewing angle of 3·9 deg., the lengths of the shadow images are given by l=41 $m_\perp h$, an increase in magnification of forty-one times. The optimum illuminating and viewing angles to choose depend upon the nature of the surface under examination ; it is clearly undesirable to obscure detail in the image by large shadows caused by using too small an illuminating angle. If a surface is covered with asperities whose shapes are very similar, for example, all having the same maximum angle of slope to the general surface, this common angle of slope can be found by taking a series of micrographs of the same area of the specimen at the same viewing angle whilst the illuminating angle is gradually reduced. Shadows will appear when the illuminating angle falls below that of the asperity slope. It is important that θ_1 should be gradually reduced from a maximum value and not gradually increased from a minimum, because of the effects of contamination of the specimen by carbonaceous deposits caused by the electron beam (Haine and Hirst, 1953).

100μin.

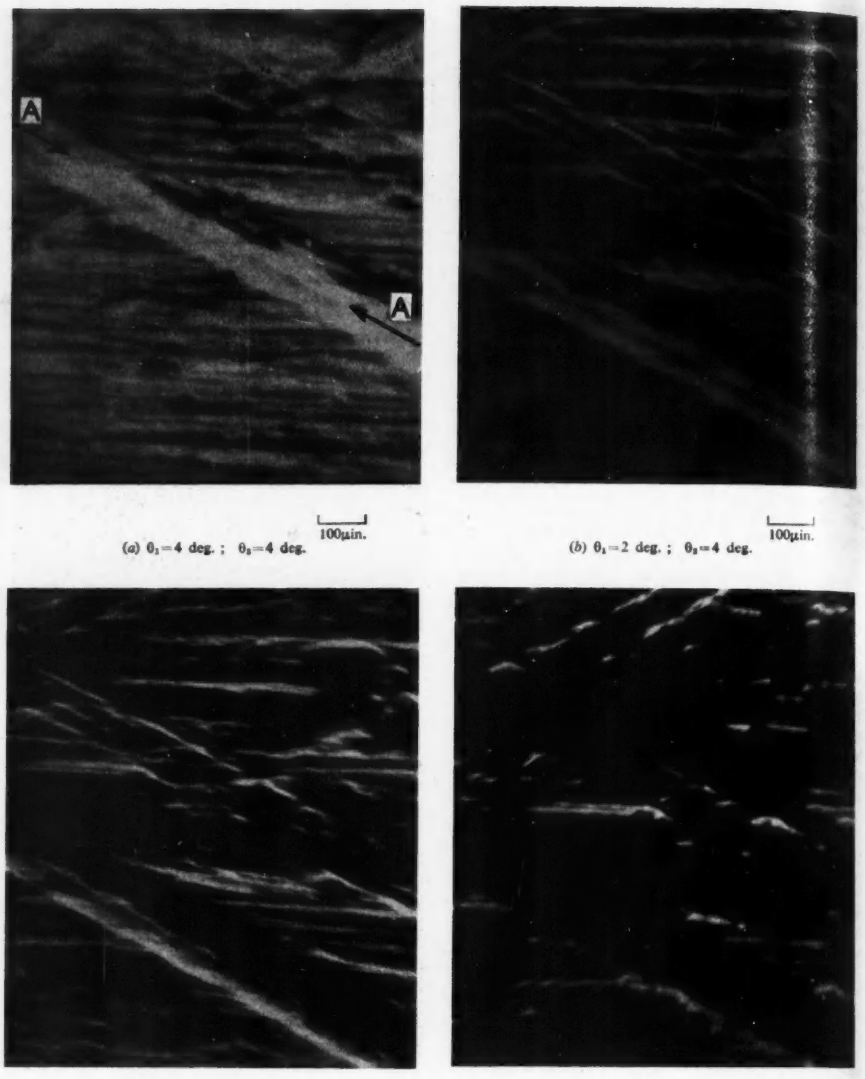
θ_1=4 deg. ; θ_2=4 deg.

Fig. 6—Nickel, ground

Results

As illustrations of the information provided by the method, two photographs will first be discussed in detail. Fig. 2 shows a surface which is so smooth that an illuminating angle of about 0·1 deg. could be used without appreciable shadows being cast. The micrograph was obtained using a specimen of pure aluminium which had been electropolished in a mixture of perchloric acid 20 per cent and ethyl alcohol 80 per cent. In the micrograph there are large areas of different density ; these are due to undulations in the surface which alter the effective θ_1 and θ_2 values for different local areas, giving rise to contrast variations (Haine and Hirst, 1953). Often valleys or steps separate the regions of different density and it is reasonable to assume that they are related to the crystal boundaries. Using Equation (2), from measurements of the shadow lengths it can be stated that none of the ridges or asperities observed were higher than 0·4μin and very often they are only of the order 0·04μin high. Apart from the valleys and fine ridges, very little other detail can be observed. There is one depression of approximately 200μin diameter which is most probably an etch pit.

Fig. 3 shows an example of a much rougher surface. The specimen was hardened tool steel which had been finished on a surface grinder using an aluminium-oxide wheel. The surface was viewed almost directly along the grinding marks (actually the plane of the incident and scattered electron beams makes an angle of approximately 3 deg. to the grinding grooves). To restrict shadows to reasonable lengths, θ_1 was made 4 deg. and also θ_2=4 deg. Whereas in Fig. 2 most of the surface topography was revealed by variations in contrast, most of the detail in Fig. 3 is revealed by shadows. Thus, grinding leaves on a tool steel surface many asperities whose sides slope at angles greater than 4 deg. to the general surface. Since the specimen had been moved by $^1/_{39}$in for each successive grinding cut, Fig. 3 does not necessarily indicate the greatest variation in depth which a single grinding operation makes, but it is typical of the small-scale damage occurring in any region of such a surface. It is obvious that the surface is rougher in any direction which is across the grinding marks, which arise from high spots on



100μin.

(*a*) θ_1=4 deg. ; θ_2=4 deg.

100μin.

(*b*) θ_1=2 deg. ; θ_2=4 deg.

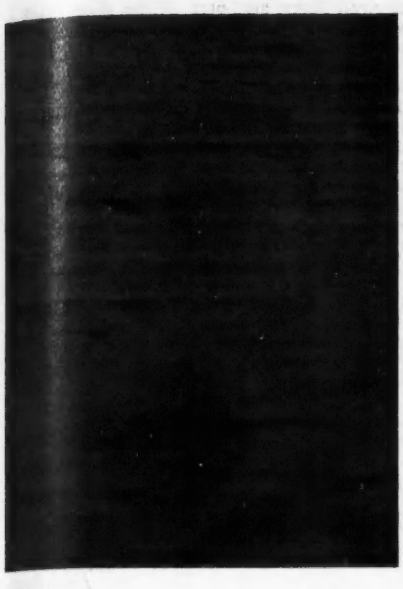
100μin.

(*c*) θ_1=1 deg. ; θ_2=4 deg.

100μin.

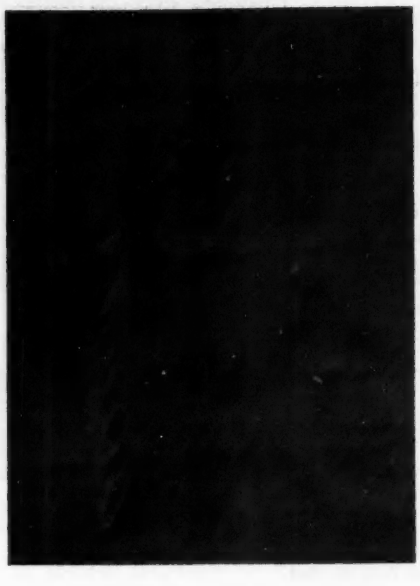
(*d*) θ_1=0·5 deg. ; θ_2=4 deg.

Fig. 7—Stainless steel, lapped



100μin.

(*a*) $\theta_1=4\cdot5$ deg. ; $\theta_2=3\cdot5$ deg.

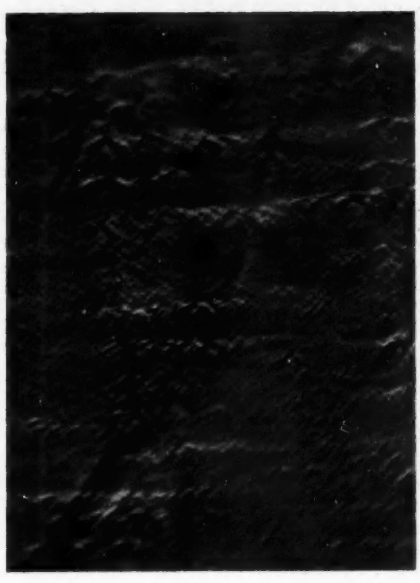


100μin.

(*b*) $\theta_1=2\cdot5$ deg. ; $\theta_2=3\cdot5$ deg.

100μin.

(*c*) $\theta_1=1\cdot5$ deg. ; $\theta_2=3\cdot5$ deg.



100μin.

(*d*) $\theta_1=2$ deg. ; $\theta_2=4$ deg.

Fig. 8—Mild steel, finely abraded

the grinding wheel, than along them, since there are relatively few isolated asperities which cast shadows as long as those cast by the grinding ridges. In fact, along the line *AA*, Fig. 3, a typical grinding path, the highest asperity is about 17μin, and along *BB* a smooth path, the highest is 3·2μin. For the highest isolated asperity *h* is about 67μin. The ridges appearing in Fig. 3 vary in height up to a maximum of approximately 68μin, and the worst scratches on this specimen (revealed by a Talysurf recording) were some 400μin deep.

As stated previously, any line traced on the tool steel surface (Fig. 3), which is directly across the micrograph—that is, at right angles to the electron beam—gives a magnified and undistorted profile. From such a profile it is seen that the highest ridge *CC* has sides which slope at approximately 30 deg. to the general surface. From this value and a measurement of the half-width of the base of the ridge its height is estimated to be 50μin. Considering the roughness of the surface and the consequent errors involved in the measurements, this value may be regarded as being in reasonable agreement with the value of 76μin estimated from the shadow length. With smoother surfaces the measurement of asperities isolated from their neighbours is more accurate.

Some micrographs will now be described which illustrate other possible applications of reflection electron microscopy in the study of surfaces. Figs. 4, 5 and 6, illustrate micrographs of ground copper, mild steel, and nickel surfaces respectively. The copper was ground with a silicon-carbide wheel, whilst an aluminium-oxide wheel was used for the mild steel and nickel specimens. In all cases the plane of the electron beam was nearly parallel to the grinding marks. Fig. 4 differs from Fig. 3 in that large individual asperities occur more often on the ground copper than on the hardened tool steel. This is probably due to the greater tendency for copper to stick on to the grinding wheel and be dragged away from the surface rather than be cleanly cut away. This interpretation is supported by the fact that when copper is being ground the wheel needs to be "dressed" more frequently than when tool steel is being ground because of the impregnation of copper particles in the surface of the wheel. This "sticking" and "dragging" effect is very pronounced when soft mild steel is being ground (Fig. 5). In this micrograph there are no continuous grinding marks visible, but the surface is covered with many large asperities. These two micrographs were obtained from typical areas of the surfaces. Fig. 6 is of a particularly smooth patch on a ground nickel surface. The cutting action of the grinding wheel, as opposed to the "sticking" and "dragging" (Fig. 5), is well illustrated. This micrograph also shows that both effects may occur when the same metal wheel combination is used. It seems that by the application of reflection electron microscopy it may be possible to evaluate directly the best grinding wheel, grinding wheel periphery speed and cutting feed for a given metal.

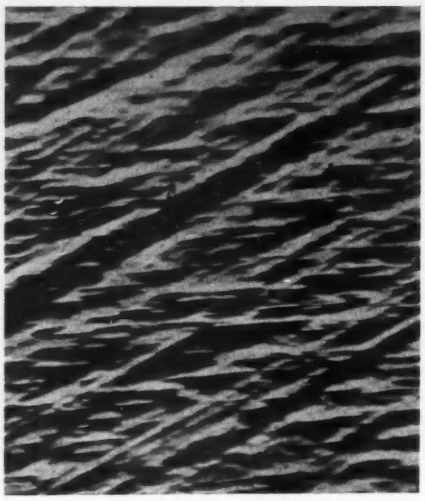
The next two series of micrographs illustrate the use of a range of decreasing illuminating angles when viewing the same area of surface at a constant angle. Fig. 7 shows a series of micrographs taken of the same area of a stainless steel surface which had been lapped on a cast iron lap using 320 grade carborundum in oil, the lapping being sufficiently prolonged to remove all traces of previous treatments. The angle θ_2 was kept constant at 4 deg. and θ_1 had the following values :—(*a*) 4 deg., (*b*) 2 deg., (*c*) 1 deg., and (*d*) 0·5 deg. Fig. 7(*a*) can be compared with the micrographs of the ground surfaces which have the same values of θ_1 and θ_2. The asperities are smaller and more uniformly distributed than those left by surface grinding. There are asperities whose sides slope at more than 4 deg. to the surface, but only a few are as high as 28μin. There are grooves in random directions but there are no pronounced undulations in the surface, since the grooves running directly across the micrograph are relatively straight. The average depth of the worst groove, *AA*, is less than 12μin and it is 68μin wide.

In Fig. 7(*b*), the "in-focus" part of the micrograph is of a slightly different area to that in Fig. 7(*a*). However, it can be seen that reducing θ_1 from 4 deg. to 2 deg. reveals some extra information. Few new shadows have been formed, but some areas which were blank in Fig. 7(*a*) show contrast variations in Fig. 7(*b*).

When θ_1 is reduced to 1 deg. (Fig. 7(*c*)) many of the details visible by contrast variation at $\theta_1=2$ deg. now give shadows. Also, many of the long shadows cast by the larger and sharper asperities which could be seen at $\theta_1=4$ deg., now obscure much of the surface detail and, in several instances, asperities are illuminated only at their peaks. The shadows which first appear in Fig. 7(*c*) are due to asperities about 2·8μin high. Thus, on the 320 carborundum lapped stainless steel surface there are a few asperities whose sides slope at more than 4 deg. to the general level, whilst large areas of the surface are covered with asperities whose sides slope at approximately 2 deg. The "sharper" asperities are sometimes as high as 28μin, but, taking Fig. 7(*a*) to be a typical area, there are fewer than 100 such asperities per square millimetre. The average height of the "sharper" asperities is approximately 8μin and the average height of the 2 deg. asperities is approximately 2·8μin.

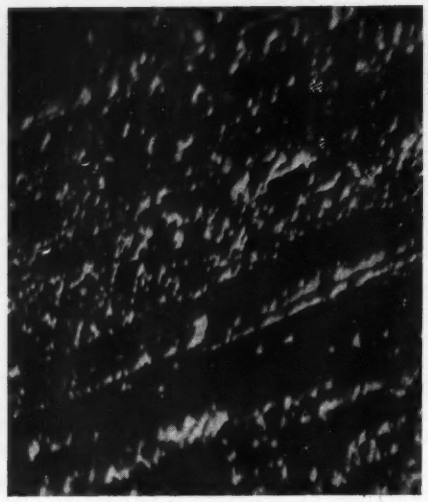
When θ_1 is reduced to 0·5 deg. (Fig. 7(*d*)) no surface detail is visible and only the very tops of the higher asperities can be seen. If such a lapped surface were brought into contact with a hard, flat surface, high spots such as those appearing in Fig. 7(*d*) would determine the location of the regions of true contact.

Fig. 8 shows a series of micrographs (*a*)(*b*)(*c*)(*d*) of an area of a mild steel specimen which had been abraded on successively finer grades of Corosil finishing paper, the final grade being the precision grade. When abrading on each successive paper the specimen was turned by 90 deg. and the abrasion continued until all traces of the previous scratches were completely removed. In (*a*)(*b*)(*c*) the final abrasions were directed from top to bottom (that is, from the back to the front of the specimen). A constant viewing angle $\theta_2=3\cdot5$ deg. was used with the following values of θ_1 :—(*a*) 4·5 deg., (*b*) 2·5 deg., and (*c*) 1·5 deg. It is obvious that along the abrasion tracks the abraded mild steel is much smoother than either the lapped or ground specimens. It is unlikely that any asperity makes an angle much greater than 4·5 deg. to the surface, and the highest asperity visible in Fig. 8(*a*) whose sides are at more than 4·5 deg. to the surface is 7·6μin. In Fig. 8(*b*) one or two scratches appear which



100μin.

(*a*) θ_1=0·1 deg. ; θ_2=3·9 deg.



100μin.

(*b*) θ_1=0·1 deg. ; θ_2=3·9 deg.

Fig. 10—Tool steel, finely abraded

were not in Fig. 8(*a*), otherwise there are no great differences between the micrographs. On decreasing θ_1 from 2·5 deg. to 1·5 deg. there is a marked difference (Fig. 8(*c*)), the whole micrograph showing profiles of tiny asperities. Changing θ_1 from 2·5 deg. to 1·5 deg. is, therefore, sufficient not only to show up the small asperities, but to cast shadows from them such that only their tips are illuminated. Fig. 9(*d*), for which θ_1 has the intermediate value of 2 deg., is a micrograph obtained from a similar area of the same specimen. The small asperities appear all over the surface, and measurements show that they are about 6·7μin wide at the base and rarely higher than 2·2μin. From Fig. 8 it can be deduced that the optimum angle of illumination for this abraded surface is 2 deg.

The two most surprising facts from Fig. 8 are (1) the smoothness of the vast majority of asperities in the abrasion direction—that is, the low angle of slope—and (2) the fact that they are so equally smooth over the whole surface.

In a direction across the abrasion marks, the slope of the asperities is much steeper ; from the base and height measurements of the small asperities, the highest must slope at least 30 deg. to the general surface level. Micrographs obtained from this abraded surface with the

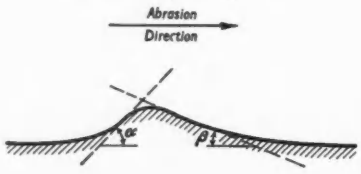


Fig. 11—Effect of abrasion direction on small asperity slopes

electron beam directed across the abrasion direction confirmed this, in that even with θ_1=6 deg. and θ_2=2 deg. shadows were cast. The shadows were mostly from long continuous ridges which cannot be seen by viewing directly along them. For θ_1=1 deg. and θ_2=3 deg., only the peaks of the highest asperities showed. The highest ridges left by the abrasion appeared as continuous lines across the whole micrograph, and many of the smaller asperities, which were visible in Fig. 8(*c*) and (*d*), appeared as short lines parallel to the major ridges. Their lengths agreed with the values expected if the asperities were assumed to be pyramidal and their lengths calculated from their heights and a slope of 2 deg.

For several abraded metals it has been found that the two long sides of the small asperities slope at different angles to the general surface. In Fig. 10 two micrographs are shown, which were obtained from finely abraded, hardened tool steel. The electron beam was at 5 deg. to the direction of abrasion and $\theta_1 \simeq 0{\cdot}1$ deg., θ_2=3·9 deg. for both Fig. 10(*a*) and (*b*), the only difference being that the specimen had been turned through 180 deg. after Fig. 10(*a*) had been taken. Similar results were obtained for finely abraded nickel, aluminium, and copper specimens and also for a buffed copper surface. A schematic diagram of this effect is shown in Fig. 11, which represents the cross section of a small asperity along the direction of abrasion. In all cases $\alpha > \beta$. With finely abraded copper the approximate values are α=2·5 deg. and β=1 deg. Often β is much smaller, for example, abraded tool steel, where β is of the order 0·1 deg. For abraded mild steel α and β are both nearly 2 deg. The inequality between α and β must arise from the mode of cutting during abrasion. Comparing Fig. 10(*a*) with Fig. 2 it is obvious how much rougher the abraded tool steel is than the electropolished aluminium.

Another example of the information which can be gained with this technique is illustrated by Fig. 12 (*a*) and (*b*). A hardened stainless steel hemisphere was slid across a finely abraded copper surface under a load of approximately 200 grammes and in the presence of kerosene. The direction of motion of the slider was at right angles to the abrasion direction. The kerosene was used to provide some lubrication and to reduce the growth of welds between the slider and the copper. In the top left-hand corner of Fig. 12(*a*) the original abrasion marks can be seen approximately at right angles to the electron beam and part of the slider track is visible, the slider motion was from the bottom to the top right-hand side as seen in Fig. 12(*a*).

In the track there are score marks and no traces remain of the original abrasion marks. The mound of debris piled up at the track side is approximately 120μin high. There are shallow undulations across the track which slope at less than 2 deg. to the surface. These hills and valleys in the track may be due to a work-hardening process, as follows :—The slider, which sinks into the surface, when in motion pushes ahead of itself some copper in the same way as it throws up a pile of debris on each side of the track. At the same time, material in front of the slider is being forced down into the bulk of the metal. Periodically, there is sufficient hard worked copper ahead of the slider to resist the downward thrust and therefore the slider must rise over and past it.

In Fig. 12(*b*) the electron beam was directed straight down the centre of the track—that is, parallel to it and in the same direction as the slider. An interesting feature is that in several places pieces of copper have been torn up from the metal, but not completely removed. The best example of this is at *A*, where the hole, the copper flake, and the shadow of the flake are all well defined, the contour of the shadow is the same as that of the flake. The approximate dimensions of the flake are : length, 1520μin ; width, 130μin, and thickness, 2·8μin (the thickness was calculated from the shadow length at the back edge of the hole). It is somewhat surprising that the base of the hole should appear so flat—in fact, as flat as the surrounding track where no rupture has occurred. In regard to the flake, it is worth noting that such a flake, oriented normal to the electron beam, would transmit 50keV electrons, and very often the peaks of sharp asperities appear bright and diaphanous for this reason—for example, Figs. 5 and 7(*d*).

Conclusions

In conclusion, it is pertinent to compare the capabilities of reflection electron microscopy with those of other established methods of surface examination. In Table II various methods have been listed with their lateral and vertical resolving powers and some comments. Generally, the most useful methods are those which permit examination of surface areas from which height measurements can be made directly (methods 1, 2, 4, 5, and 6). Of these the best vertical resolution is obtained by the multiple beam interference techniques developed by Tolansky, but these have the disadvantage of poor lateral resolution. The interference microscope has slightly inferior vertical, but superior lateral, resolution and is suitable for the investigation of small shallow asperities, whilst the light profile technique can only be used for examination of

100μin.

(*a*) θ_1=2 deg. ; θ_2=4 deg.

100μin.

(*b*) θ_1=1 deg. ; θ_2=4 deg.

Fig. 12—Track on copper

TABLE II—*Resolving Powers of Various Methods for Surface Examination*

	Method	Resolution, μ inch		Comments
		Lateral	Vertical	
1	Reflection electron microscopy ...	1·2→17·0	1·2 ~0·90→0·03	The maximum lateral resolution is across the electron beam ; the first vertical resolution is from profiles, the second from shadows
2	Electron microscope replicas... ...	0·2	0·2 0·1	Vertical resolution using stereo device Vertical resolution using shadowed replica, angle of shadowing $\tan^{-1} 0·3$
3	Optical microscope...	14 10	>7* >9*	Dry objective, N.A. 0·95, green illumination Oil immersed, N.A. 1·3, green illumination
4	Light profile (Tolansky 1952) ...	10	10	Using optimum optical microscope conditions
5	Interference microscope (Dyson 1953)	10	0·1	Vertical resolution only obtained for an optimum object, for example, step between parallel flats
6	Fizeau multiple interference fringes	200	0·02	Unsuitable for matt surfaces or those having inclinations greater than 5 deg. to the optical flat
7	Reflecting microscope (Bureh 1947)	10	>14*	N.A. 0·65, ultra-violet illumination
8	Profilometers	100→50	10·0→0·2	Finite size of stylus limits the utility, also stylus scores soft materials
9	Taper sectioning (Nelson 1940 ; Moore 1948)	10	1·0	Sectioning angle $\tan^{-1} 0·1$; optimum optical microscope conditions

* Approximate depth of field of the photomicrograph.
N.A. Numerical aperture of objective.

large asperities. For complex surfaces, for example, a lapped specimen, the information contained in an interference micrograph is often so complicated that its interpretation is impracticable. The best lateral resolution is attainable using the electron microscope replica techniques, and quantitative information about the vertical features of replicas can be obtained by shadowing. At present the minimum angles of shadowing used are much greater than can be obtained with the reflection method. To reveal small asperities similar to those illustrated in Figs. 8 (*c*) and (*d*), the shadowing angles must be of the order 1 deg. Theoretically, when replicas and such a low angle of shadowing are used, features of the order 0·004μin high should be detectable, but it is doubtful whether replicas could faithfully reproduce surface undulations to this degree. When rough surfaces are being examined it is difficult to remove replicas without breakage, and for the examination of features such as a loosely adhering flake the replica method is impracticable, owing to the danger of disturbing the flake when peeling the replica from the surface.

Thus, whilst the lateral resolution of the replica technique is greater, the reflection electron microscope has the advantages of direct examination of the specimen and the ability to use low angles of illumination when necessary. The wide range of surface textures which can be examined and the undistorted profiles obtained are further advantages of the reflection method over all the others. Probably, however, a most complete examination of the small-scale surface features of interest in engineering will require a combination of reflection electron microscopy and the replica technique.

Cable Rating and Soil Thermal Resistivities

THE following statement is issued by the Cable Makers Association, with the authority of all British cable makers (including firms outside the C.M.A.) concerned with the production of impregnated-paper-insulated power cables for any voltage.

The forthcoming publication by the British Electrical and Allied Industries Research Association of a new booklet (reference F/T 183) entitled, " Current Ratings for Paper Insulated Cables to B.S. 480 : 1954, and Varnished Cambric Insulated Cables to B.S. 608 : 1955," contains two tabulated sets of ratings for cables laid direct in the ground (and for cables in underground ducts) based on two alternative values for soil resistivity, namely, $g=120$ and $g=90$.* This is a departure from past practice because in the earlier ratings published by B.E.A.I.R.A. (reference F/T 128) all ratings for cables laid direct in ground or in ducts were tabulated for just the one value of soil resistivity, namely, $g=120$. It was possible, however, to obtain the rating for any other value of g from a curve of correction factors which was given in the same booklet.

In the new publication, these correction factors are still included, but instead of giving them in the form of a curve, actual factors are tabulated for fixed values of g, namely, 60, 150, 180, 210, 240, 270, and 300, with the advice that in order to take account of irregularities in soil conditions along the route the current rating or rating factor appropriate to the value next above the maximum measured value should be used. Soil thermal resistivity measurements should, therefore, be an essential preliminary to the determination of the correct current rating for a given cable, and it is to be hoped that one effect of this new publication will be to encourage users to determine soil resistivities along their cable routes in order that the correct current rating can be applied. The situation, however, must be faced where such figures for soil resistivity are not available or are not readily obtainable.

Hitherto, the practice has been to assume a soil resistivity of $g=120$, and the result has been eminently satisfactory. The publication of tabulated ratings for a lower value of g in no way affects the position and the cable industry of this country will continue to base their current ratings on $g=120$ in all cases where a more precise figure is not available. In thus continuing a long-established practice, the industry is not being unduly conservative or pessimistic, because there is very good reason to believe that in many instances soil conditions in this country fall within the range 90–120 and, as already stated, to take account of irregularities along the route, the cable rating should relate to the highest value and not the lowest or the average.

Nowadays, there is an increasing tendency to operate cables at or near their maximum limit of temperature by, for example, taking proper cognisance of the actual shape of the load curve and applying peak ratings which are substantially in excess of the tabulated continuous ratings. This practice, correctly applied, is safe because it does not involve the maximum safe temperature of the cable being exceeded. Furthermore, the maximum operating temperature of all cables for working voltages up to and including 6·6kV has already been increased by 10 deg. Cent. and the current ratings increased accordingly.

In view of the above, the actual value of the thermal resistivity of the soil becomes more important. The procedure, therefore, which the British cable manufacturing industry recommends as soon as the new ratings are published, may thus be summarised : Wherever possible, actual measurement of soil resistivity should be taken at suitable intervals along the route, or otherwise the probable maximum soil resistivity should be assessed from the information given about different soils in the new publication. When neither course is practicable, the cable rating should be that corresponding to $g=120$.

* The thermal resistivities of a material, g, is the temperature difference in deg. Cent. between opposite faces of a centimetre cube of the material to produce a flow of heat of 1W, and is expressed as so many " thermal ohm-cm " or " deg. Cent. cm per watt."

Mobile Excavating Machine

A MOBILE excavator, which can readily be adapted as a shovel, back trencher, grab or crane, is now being made by Chamberlain Industries, Ltd., Staffa Road, Leyton, London, E.10. All movements of this machine are hydraulically-controlled, and its general construction can be seen in the accompanying illustration. It is built as a complete unit suitable for mounting on a vehicle chassis of suitable capacity. In the equipment illustrated, hydraulic power is supplied by a diesel-engine-driven pump mounted on the rear of the platform, but if required a pump driven from the power take-off of the vehicle engine can be used.

The machine is mainly of heavy fabricated steel plate construction, and its platform is mounted on a double row of balls, on which it is rotatable through a full circle in each direction by a hydraulic motor. The main jib is supported at its foot by large trunnion bearings in a rigid bracket structure on the platform. A double-acting hydraulic cylinder, mounted between the jib and a forward extension of the platform is used to raise and lower the jib. A shovel arm pivoted at the top of the jib is actuated by a second double-acting cylinder, and a third cylinder, mounted on top of this arm, can be introduced into service depending on the particular duty required of the machine. This third cylinder is used to impart the swing movement to a trenching bucket, open and close a grab or to actuate a short outrigger arm fitted with a crane hook.

The equipment is designed to work with a standard bucket capacity of 10 cubic feet. When it is operating as a shovel or trencher, it has a maximum discharge height of 14ft, a shovel excavating depth of 3ft, and a trench excavating depth of 6ft. In excavating work the maximum operating radius is 14ft 9in, whilst the maximum trenching radius is 16ft 5in.

All movements are controlled by four levers arranged conveniently in front of the operator's seat, which is situated at one side of the platform, from where an unobstructed view is given of all working movements.

Hydraulically-operated mobile excavator with 10-cubic-foot bucket

Hot Extrusion of Carbon Steel

BY OUR AMERICAN EDITOR

FOLLOWING earlier installations by such American steel companies as the Allegheny-Ludlum Steel Corporation, the Babcock and Wilcox Company, the H. M. Harper Company, and the National Tube Division of the U.S. Steel Corporation, another hot extrusion plant based on the Ugine-Sejournet glass lubrication process has now gone into operation at the Pittsburgh Works of the Jones and Laughlin Steel Corporation. Initially, the plant (Fig. 1), which has been installed in a new building 60ft wide and 260ft long, will produce extrusions in solid sections, ranging in weight from ¼ lb to 12 lb per lineal foot, and up to 24ft in length. The major part of the production will consist of complex sections that cannot be rolled, but there will also be small tonnages of rollable special sections for which rolling is uneconomical. It is felt that many parts now being made from castings, forgings or machined to intricate cross section from solid bar stock, can be replaced with substantial savings, by hot-extruded, cold drawn sections. The close tolerance of the resulting sections allows the fabricator to use most of the extruded sections practically as they are. Generally, all the fabricator has to do is to cut the sections to the required lengths.

The extrusion press was designed to the company's specifications and built by Loewy-Hydropress, Incorporated, of New York. It is hydraulically powered, has a horizontal stroke and can operate at pressures up to 1000 tons. The process follows the sequence illustrated. Hot-rolled rounds from the bar mills of the company are cut to billets of predetermined length by a "Bardons and Oliver" automatic cut-off lathe. The size of the billets varies from 4in in diameter by 6in long to 5in in diameter by 20in long, with a maximum weight of 110 lb. The billets are heated in a "Magnethermic" induction heating unit, which is provided with an inert gas atmosphere. The billet passes through a preheat coil, then through a high-heat coil, where it is heated to 2300 deg. Fah. The two heating steps take only one minute. When they emerge from the heating unit, the billets roll through powdered glass, which serves as the die lubricant. An automatic loader picks up the billets and transfers them to the loading end of the extrusion press. In the extruding operation, the hydraulic ram positions the hot billet and then pushes it through the die.

The extruded bar is conveyed automatically to a cooling bed and, after cooling, the bar is stretcher-straightened and detwisted. The sections are then passed through an "American Wheelabrator" shot-blasting machine which removes the glass and scale from the bars. To provide the bars with close dimensional tolerances and a fine finish, they are subsequently cold-drawn on the cold finishing plant of the company. The dies for the extrusion press are made of tungsten-chromium steel, and after each hot extrusion, the residual glass lubricant is shot-blasted from the die. The production of extrusions at the new plant is taking place under licence from the Comptoir Industriel et Profilage de Metaux, of Paris.

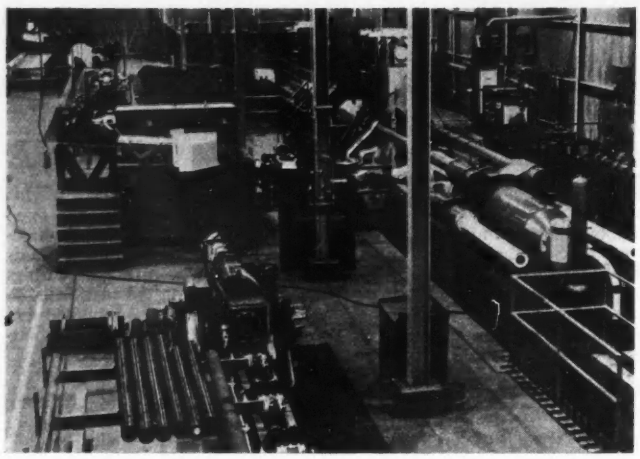


Fig. 1—Overall view of hot extrusion plant at Pittsburgh

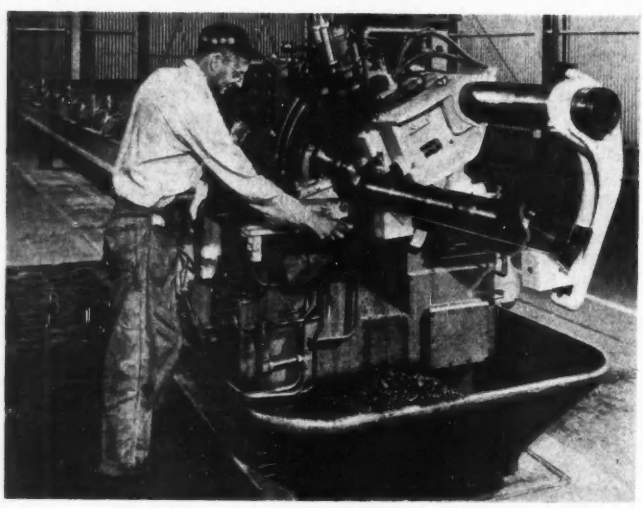


Fig. 2—Extrusion billets being cut off on automatic lathe

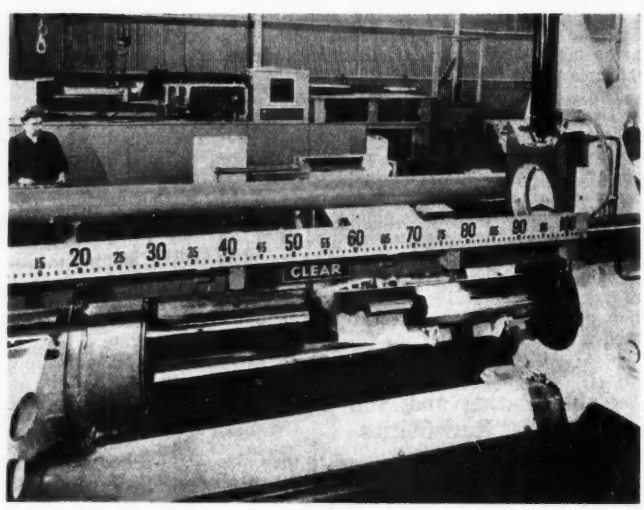


Fig. 3—White-hot glass-coated billet prior to extrusion, with induction heating unit in background

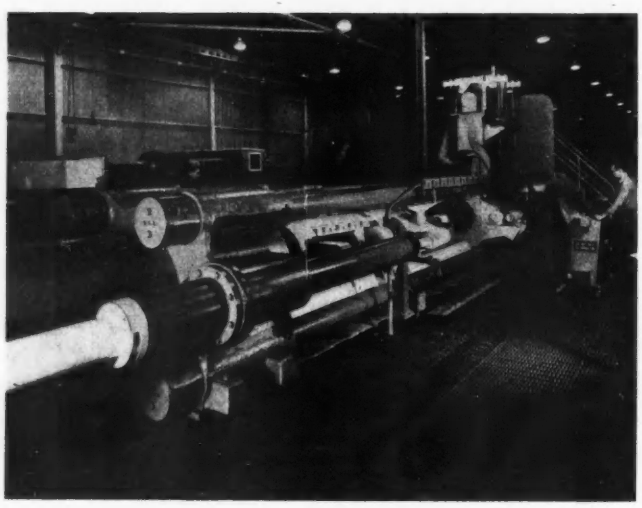


Fig. 4—1000-ton horizontal hydraulic extrusion press

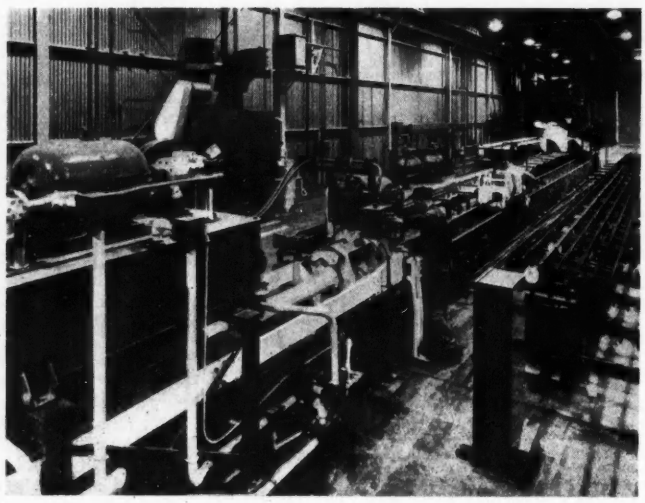


Fig. 5—Automatic cooling table and stretching-detwisting machine for hot-extruded sections

More Toll Roads

The recent announcement by the New Jersey Turnpike Authority that it would add two more traffic lanes to 61 miles of its three-year-old toll road, illustrates a very real problem which is facing many American highway authorities : whenever a post-war turnpike has been completed, the growth of traffic using the route has far exceeded the engineering estimates upon which the road and its financial structure were predicated. The race between highway builders and highway users had its inception with the New Jersey turnpike, the first of the post-war toll roads to demonstrate conclusively that American motorists were willing to pay cash for time saved. Since then a complete network of toll highways has been constructed or is nearing completion to provide travel free of traffic lights from the North-East to the Middle West of the United States. Within two years " super-highways " will link Augusta, Maine, with Chicago, Illinois, by way of the Maine, New Hampshire and Massachusetts turnpikes, the New York Thruway and the Pennsylvania, Ohio and Indiana turnpikes. Those toll roads which already are in operation are making more money than conservative engineers estimated was needed to make the respective schemes self-liquidating. But recently a note of caution has been sounded by consulting engineers and financial advisers to the investment bankers who have been underwriting toll road bonds. In the opinion of these experts the phenomenal growth of the New Jersey turnpike might be misleading as a basis for the comparison of other toll road structures. The New Jersey road is a corridor that links the first and third largest cities of the country—New York and Philadelphia. It is in the centre of the important group of Eastern and North-Eastern States that have 24 per cent of the country's population and 35 per cent of its industrial production. In addition, there are less than 2000 miles of New Jersey State highways to absorb the daily flow of traffic ; on the other hand, in the Middle West there are many excellent free highways.

The traffic volume on the New Jersey turnpike exceeds that of any toll road in the world. The highway carried 25,000,000 vehicles last year, which constitutes roughly two and a half times the consulting engineers' predictions ; they estimated that a volume of 25,000,000 would not be reached until 1981. The steadily increasing traffic on the New Jersey turnpike, which cuts diagonally across the State from near the George Washington Bridge to Deepwater, where it connects with the Delaware Memorial Bridge, has made it imperative for the Authority to widen the section from the northern terminus to the Lincoln Tunnel " interchange " from four to six lanes and to do the same thing on the section from Woodbridge and the Amboys to Camden. This improvement will provide 83 straight miles of six-lane divided highway travel, since the link from the Lincoln Tunnel to the Amboys was originally constructed for six lanes of traffic. Widening of the roadway started this spring. It should be adequate to handle the traffic for at least four years. Already, the consulting engineers have taken into consideration the added demands that will arise when two important extensions are completed in 1956. One extension will enable traffic to by-pass the Hudson County peninsula by providing a direct connection from the Newark Airport " interchange " to the Holland Tunnel and will cost 118 million dollars. The other extension will tie together the New Jersey and Pennsylvania turnpikes by way of a bridge across the Delaware River. This will provide another link in the " super-highway " chain from the New York area to the Middle West. The cost of the bridge is being shared by the agencies of the two States and New Jersey is constructing a 6-mile-long approach from the Bordentown " interchange " to the bridge. On the Pennsylvania side, the Pennsylvania Turnpike Commission is building a 30-mile highway that will enable through traffic to by-pass the congested North Philadelphia area.

Although confident that the widening of the New Jersey toll road and the building of its extensions will make for smooth traffic flow for the next five years, the consulting engineers are now starting to worry about the impact of the proposed Narrows Bridge, which is to connect the boroughs of Brooklyn and Staten Island in New York City. The main functions of this suspension bridge is to enable Long Island and Westchester motorists heading south or west to by-pass the congested local street system of New York. If the structure, which would be the longest in the world, becomes a reality, there is no forecasting how much more load would be channelled on to the New Jersey toll road. But there is little doubt that it will be enough to compel the authority to widen the southernmost 35 miles from Camden to the Delaware Bridge from four to six lanes. Thus, the New Jersey turnpike provides an almost incredible example of a well-planned and carefully designed modern toll road becoming inadequate for its traffic load within only four or five years of its opening. However, highway planners in other parts of the world will be well advised to consider this particular case history against the exceptional geographical conditions applicable ; it would indeed be foolish to hope for similar traffic—and revenues—in the absence of that combination of unusual factors which now make the New Jersey turnpike the most heavily travelled toll highway in the world.

Automatic System for Mass Production of Electronic Devices

SOME time ago the Bureau of Aeronautics of the U.S. Navy released certain information concerning an automatic production line for the manufacture of electronic devices and a system of electronics design which makes this possible. The development of the system took place at the National Bureau of Standards under the sponsorship of the Bureau of Aeronautics, and the system was code-named " Project Tinkertoy," probably because it is based on the principle of the building blocks with which children play. Both the design system and the methods of component manufacture were reviewed in THE ENGINEER of May 28, 1954. Since that time, the National Bureau of Standards has developed additional components and manufacturing techniques under the sponsorship of the U.S. Navy Bureau of Aeronautics, including an adhesive tape capacitor, a " chip " resistor, and a method for applying pyrolytic carbon resistors. It is believed that these additional components and techniques should do much to increase the versatility and applicability of electronic equipment manufactured by automatic production lines.

It may be recalled that the development of systems for modular design of electronics (" M.D.E.") and mechanised production of electronics (" M.P.E.") was initiated by the Bureau with the co-operation of several industrial companies as a measure of industrial preparedness. The system starts with raw or semi-processed materials and automatically manufactures ceramic base wafers, dielectric elements for capacitors and adhesive tape resistors, prints conducting circuits and capacitors and mounts resistors, capacitors and other component parts on standard, uniform steatite wafers. The wafers are stacked like building blocks to form modules (Fig. 1) which perform all the functions of one or more electronic stages. The pilot production plant, which is operated by a commercial contractor, incorporates the principles of this system and was designed to produce 1000 finished and inspected modules per hour.

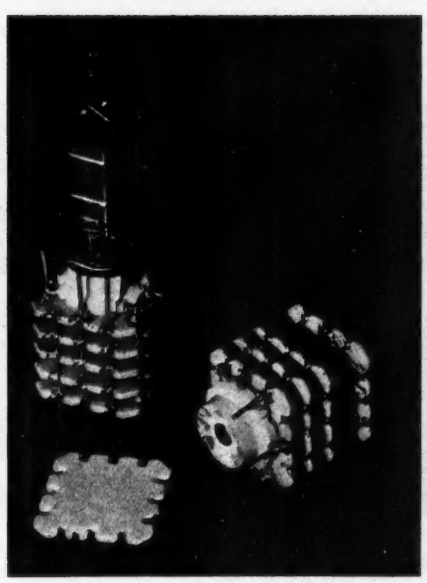


Fig. 1—Module sub-assemblies and individual wafer

THE TAPE CAPACITOR

The self-adhesive tape capacitor (Fig. 2) was designed specifically for application to the ceramic wafer by the combined " M.D.E."-" M.P.E." techniques. It is manufactured in much the same manner as the adhesive-tape resistor. A conducting tape, coated on one side with a dielectric, provides one element of the capacitor. The other element is a silver pattern printed and fired on the wafer. It is now possible to apply an adhesive-tape resistor to one side of a wafer and an adhesive-tape capacitor to the other side. The materials required for the manufacture of tape capacitors are a heat-resisting asbestos paper tape, silver flake, silicone resin, butyl cellosolve, a powdered high-K titanate body, N-hexane, and epoxide resin. The electrically-conducting formulation (a mixture of the silver flake, silicone resin and solvent) is ground in a ball mill. The mixture is sprayed on a loop of tape 1¼in wide, allowed to dry thoroughly, and then sprayed on the other side. When cured, the metallised tape is conductive along each side and from one side to the other. After slitting along the centre to form two ¾in wide tapes, it is ready for application of the dielectric film. A roll of tape 19ft long will produce about 350 capacitors.

The dielectric formulation is composed of high-K titanate body that has been pulverised in a ball mill with N-hexane until the particle size is about 1 to 2 microns, after which the slurry is allowed to evaporate under a hood. The ground titanate body is mixed with epoxide resin and further ball-milled. This tacky dielectric mixture is then sprayed (Fig. 3) on the metallised base tape in various thicknesses determined by the number of passes the tape

makes in front of the spray gun. Thicker applications, of course, result in capacitors of lower value. The silver pattern which forms one electrode of the capacitor is applied to the steatite wafer by means of a screen press. It is then dried and fired on to the ceramic. The adhesive dielectric-coated tape which forms the other electrode is cut into squares slightly larger than the silver contact and pressed down on it. A narrow conductive strip, similar to resistor tape but with a conductivity of approximately 0·02 ohm per ¼in, is laid down between a contact on the edge of the wafer and the top side of the capacitor. The complete assembly is then cured by placing it in an oven at room temperature, raising it to 225 deg. Cent. over a period of half-hour, and holding the temperature at 225 deg. Cent. for forty-five minutes.

Capacitors of higher values can be manufactured by applying a number of layers of tape, one on top of another, with appropriate connections to the edge of the wafer. Smaller capacitors can be made by reducing the area of the silver pattern printed on the wafer, or by increasing the thickness of the dielectric layer. Shelf life tests indicate that the capacitance changes no more than 1 per cent during the first month after manufacture, and that there is no change in the dissipation factor, which averages 0·7 per cent at 1 kc/s. However, the capacitance does change somewhat with temperature, changes of −3 per cent from 25 deg. Cent. to 85 deg. Cent., and of −15 per cent from 25 deg. Cent. to −55 deg. Cent. having been observed. In a load life test, a few capacitors shorted out, but otherwise only negligible changes occurred in the capacitance and the dissipation factor.

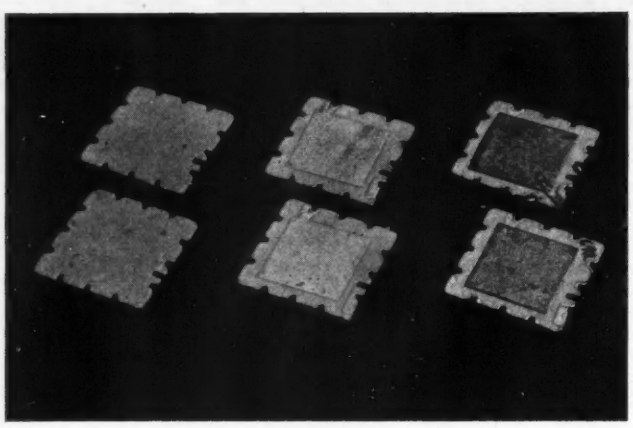


Fig. 2—Three stages of tape capacitor production

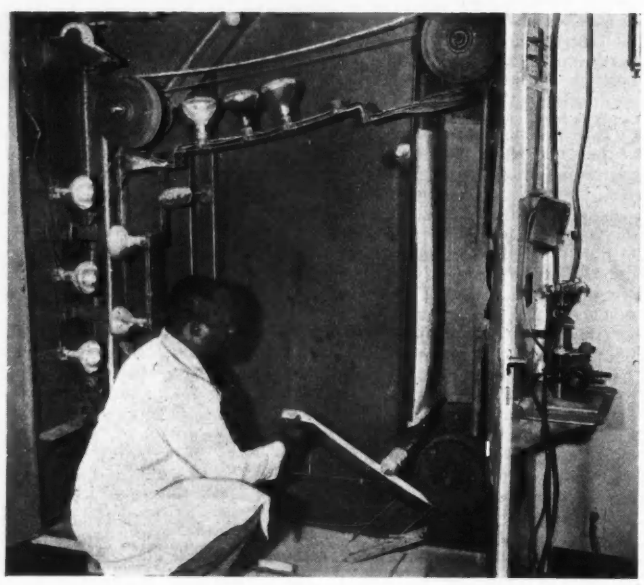


Fig. 3—Chamber for spraying electrically conducting and dielectric solutions on capacitor tape

The "Chip" Resistor

The "chip" resistor (Fig. 4) is made by applying self-adhesive resistor tape to a small chip of ceramic material. This resistor is not intended for use in the regular quantity production of modules, but aids the electronic design engineer in studying new modular circuits which are still in the trial stage or in producing prototype equipment for evaluation purposes. The chip is inserted into a circuit simply by soldering it to the appropriate connections on a standard wafer. The precured resistor tape is manufactured automatically by the usual "M.D.E."-"M.P.E." techniques, but is applied to a chip of cured steatite about 0·600in long by 0·225in wide instead of the standard unit wafer. A prototype machine developed in the N.B.S. laboratories mounts the resistor on the chip. The chip, with its tinned and silvered connecting tabs already fired on to each end, is automatically oriented properly in a shallow die. A roll of tape of the desired resistance value is fed into the machine and is die-cut to a size of 0·5in long by 0·125in wide to overlap the metallised tabs on each end. The machine then presses the cut tape, adhesive side down, on to the ceramic chip. When this operation is completed, the chip resistor is ejected from the machine into a hopper and is ready to be cured. The final machine will be entirely automatic, will require no attention other than the supply of steatite chips and resistor tape, and will be capable of manufacturing 1000 chip resistors per hour.

The Pyrolytic Carbon Resistor

The pyrolytic carbon resistor (Fig. 5) is a miniature component made by a process which was developed at the Bell Telephone Laboratories. Because this resistor may be manufactured in large quantities to close tolerances, the Bureau has adapted it to the "M.D.E."-"M.P.E." methods by inserting it in a specially designed wafer to produce a unit that is wholly compatible with other units of the module system. The resistors are either flat or cylindrical and are about ⅜in long by ⅛in wide or $\frac{1}{16}$in in diameter. Although not yet in regular production, these carbon-film resistors are being manufactured for small production runs under licence from the Western Electric Company. They are made by cracking or decomposing methane gas in a high temperature environment which also contains the miniature ceramic forms. Pure carbon is deposited on the ceramic in accurately controlled thicknesses. The coated forms are then either grooved or spiralled mechanically to increase the electrical path length and to decrease the path cross section. Accurate control of resistance is achieved in this way, and the finished resistor is within 2 per cent of its design value.

An "M.D.E."-"M.P.E." wafer having an appropriately shaped depression receives the carbon resistor. The depression has printed conducting paths on each end to provide connection from the resistor terminals to the riser wires of the completed module. After the resistor is inserted into the wafer, it is terminated with a silver thermo-setting resin mixture and cured at 150 deg. Cent. for two hours or at 200 deg. Cent. for half-hour. It is then ready to be assembled on the automatic production line into a module with other electronic components.

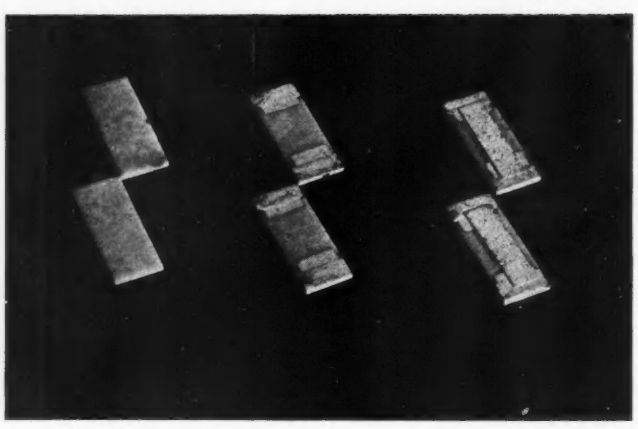


Fig. 4—Three stages of "Chip" resistor production

Fig. 5—Two stages of pyrolytic carbon resistor production

Industrial and Labour Notes

Overseas Trade

Provisional figures about the United Kingdom's overseas trade in March, which have been issued by the Board of Trade, give the value of exports as £260,300,000. There were twenty-seven working days in the month. In the first quarter of this year, exports of United Kingdom goods averaged £247,300,000 a month, which was 10 per cent higher than in the comparable period of last year. Taking the last six months, October, 1954, to March, 1955, together, the value of exports was 3 per cent higher than in the corresponding period a year earlier.

Imports in March were valued at £365,400,000, which figure, the Board of Trade says, reflects many orders placed last year. The average value of imports during the first quarter was £335,500,000 a month, or 23 per cent more than in the first quarter of last year. The value of re-exports in March was £12,700,000, the monthly average during the first quarter of this year being £10,600,000. The excess of imports over total exports was, therefore, £77,600,000 a month in the first quarter.

About wholesale prices, the Board of Trade says that last month the indices for materials used in the mechanical engineering and electrical machinery industries continued their upward movement and that over the first quarter of this year they showed rises of 5·4 per cent and 9·4 per cent, respectively. The rise in these two indices between February and March was due to higher prices for various brass and copper items. At the end of March the price index numbers (June 30, 1949=100) were 164·2 for materials used in the mechanical engineering industries and 184·2 for materials used in the electrical machinery industry. For building and civil engineering materials the price index was 135·2, which indicated an increase of 0·1 per cent during March.

Competitive Prices

Some comments on costs, in their relation to competitive prices, are made by the information division of the Treasury in *Bulletin for Industry*, its monthly review of the economic situation. It is emphasised—yet again—that an increase in exports is needed to match the high rate of imports and rebuild the balance of payments surplus. For that to be achieved, the *Bulletin* says, depends, even in a world market that may have expanded further, on whether our prices are competitive with those of Germany, the U.S.A., Japan and other industrial and exporting countries.

It is then explained that final prices are made up of import costs and home costs. In the general make-up of prices import costs are much less important than home costs, in fact, it is stated that of the rise of about 10s. in the pound in the United Kingdom price level since 1946, under 2s. 6d. resulted from import costs as such. But when they provoke claims for higher incomes dearer imports also force up home costs. Import prices, having fallen since early 1952, levelled off in 1954 and at the end of the year turned up sharply. Home costs depend on the relation between the level of money incomes and the volume of production. Last year in manufacturing industry wage and salary earnings and profits rose by about the same proportion as productivity and there was little change in home costs. In the economy as a whole, however, money incomes rose a little faster than production, a factor which was reflected in higher final prices. But, on the average, export prices of manufacturers did not change significantly during the year.

The *Bulletin* goes on to say that the recent increase in import prices makes the present position less favourable, and if final prices are to remain stable home costs must make way for the increase in import costs. So far, the import costs of materials is not very large and there have been some signs that the rise in commodity prices pushing up import costs may have levelled off. Home costs, on the other hand, are not easing. Recently, the *Bulletin* observes, there has been a spate of wage increases, and unless the growth of productivity is well maintained there is a danger that labour costs may tend to rise. It is impossible to say, the *Bulletin* adds, what has been the trend of profits in recent months, but company trading profits reported in January and February, relating to accounting periods ending on average last autumn, were 6 per cent higher than a year earlier and ordinary (net) dividends were 13 per cent higher. The course of home costs, the *Bulletin* stresses, and hence our competitive position, will depend on how far the growth of money incomes is matched by improvement in productivity.

Railway Wage Dispute

At the end of last week, the Railway Staff National Tribunal rejected a wage claim for locomotive drivers, firemen and cleaners which was made originally by the Associated Society of Locomotive Engineers and Firemen towards the end of last year. The claim was for an all-round increase of 8s. a week. In its review of railway wages in January, the British Transport Commission made an offer which provided for a maximum wage of £9 15s. a week for drivers and motormen and £7 15s. a week for engine cleaners. That offer was accepted by the National Union of Railwaymen, of which a relatively small proportion of the footplate men are members, but it was refused by the Associated Society of Locomotive Engineers and Firemen, which insisted on going forward with its initial claim. The granting of the demand would mean additions ranging from 1s. 6d. to 5s. 6d. a week on the Transport Commission's offer. The Railway Staff National Tribunal, which is the final stage in the accepted negotiating machinery, made an award in support of the Transport Commission's offer, and said that the new rates should apply as from January 10th last.

On Saturday, the executive of the Associated Society of Locomotive Engineers and Firemen described the Tribunal's decision as "totally unsatisfactory." It claimed that, if made effective, the decision would "seriously distort the wage differential position laid down for locomotive men by the tribunal itself as recently as November last." In the circumstances, it was added, and "having regard to the vital importance of the principle involved," the executive committee of the A.S.L.E.F. had decided by a unanimous vote to reject the finding of the tribunal and to withdraw the labour of its members as from midnight on Sunday, May 1st.

The British Transport Commission made a statement on the matter on Monday in which it said that it was prepared to accept and operate the Tribunal's award. The Commission expressed its regret over the decision of the A.S.L.E.F. to take strike action. That decision, it said, if implemented, would not only cause great inconvenience to the public, but would also result in serious consequences to the railway industry and to the future prospects of those in its employ. The Commission, therefore, asked the executive of the A.S.L.E.F. to reconsider its decision, both in the interests of the industry and of the country as a whole. The union executive met again on Tuesday, but it was stated afterwards that it had not altered its decision to call a strike.

Iron and Steel Production

The Iron and Steel Board states that British steel output averaged 394,900 tons a week during March, which represented an annual production rate of 20,536,000 tons. Pig iron production averaged 240,700 tons a week and was thus at an annual rate of 12,516,000 tons.

In a survey of the results of the first quarter of this year, the Board says that steel production totalled 5,074,000 tons, and was at an annual rate of 20,295,000 tons, compared with a rate of 18,777,000 tons in the corresponding quarter of last year. It is expected that steel output this year may well be 19,500,000 tons, and it is stated that every effort is being made to arrange raw material supplies on a basis which may make it possible for production to exceed that estimate.

The pressure of demand for steel from home industries has continued to be heavy throughout the first quarter and order books show a rising tendency. There are still problems of meeting expanding requirements in some cases. On the basis that total supplies of steel are likely to be between 9 per cent and 10 per cent greater this year than in 1954, the Board says that supplies to home users should increase from just over 16,500,000 tons delivered in 1954 to over 18,000,000 tons delivered this year.

London Newspaper Printing Dispute

On Wednesday evening of last week, there was published by H.M. Stationery Office the report of the Court of Inquiry appointed by the Minister of Labour to examine the causes and circumstances of the London newspaper printing dispute. On March 25th electricians and engineering maintenance workers employed in the printing establishments of London daily and evening newspapers began a strike on account of the rejection of a wage claim by the Newspaper Proprietors Association. The men concerned are members of the Electrical Trades Union and the Amalgamated Engineering Union. Their claim was for an addition of £2 18s. 6d. to their existing basic wages. The Newspaper Proprietors Association had made an offer, which was refused by the two unions, and subsequently said that it was willing to submit the case to arbitration and would accept the arbitrator's decision. That proposal, however, was rejected by the unions.

The report of the Court of Inquiry, of which Sir John Forster, Q.C., was the chairman, sets out the history of the dispute, and also puts forward certain comments and conclusions. The report says, for example, that "the maintenance engineers, electricians and electricians' assistants have long been regarded as an integral part of the newspaper printing and publishing industry, a circumstance which has operated to their advantage, and one which they have never, hitherto, sought to alter." The report goes on to express the court's view that the rates of wages of engineers, electricians and electricians' assistants should continue to find their place within the wage structure of the newspaper printing and publishing industry in which they are engaged. Such rates, it is added, must bear fair comparison with those applying in the general engineering industry, and a broad relationship on the basis of skill and importance to those of the other sections of craftsmen in the newspaper industry. In the light of the existing wage pattern in the newspaper printing industry, the court of inquiry described the claim of the electricians and maintenance engineering workers for an additional £2 18s. 6d. a week as "unrealistic."

The report suggests that the fourteen unions with which the Newspaper Proprietors Association customarily makes agreements should co-operate in the establishment of an appropriate central body to undertake negotiations on questions of "common concern." Pending the establishment of such a body, the court urged that the men on strike should return to work "without prejudice on the basis of the employers' present offer." On Thursday of last week representatives of the Newspaper Proprietors Association and of the two unions concerned had meetings with the chief industrial commissioner of the Ministry of Labour. Their conversations lasted all day, but the unions would not then agree to a resumption of work on the basis of the court's suggestion. Meanwhile, members of the unions comprising the Printing and Kindred Trades Federation employed in the London daily newspaper establishments had to cease work last Friday following a fortnight's notice. On Tuesday last, there was a meeting of the Newspaper Proprietors Association and representatives of the two unions whose members have been on strike. A settlement was then made, and it was agreed that there should be a resumption of work pending further negotiations.

Personal and Business

Appointments

SIR PERCY H. MILLS, Bt., has joined the board of Lancashire Dynamo Holdings, Ltd.

MR. J. RUTTER has been appointed a technical representative of the Jenolizing Company, Ltd., 13–17, Rathbone Street, London, W.1.

MR. TIMOTHY ELLIS has been appointed an assistant secretary of The General Electric Company, Ltd. Magnet House, Kingsway, London, W.C.2.

THE ENGLISH SALVI COMPANY, Ltd., 11, Kensington Church Street, London, W.8, announces the appointment of Mr. C. F. Bolton as consulting engineer.

THE MINISTER OF TRANSPORT AND CIVIL AVIATION has appointed Captain A. M. A. Majendie to be a member of the council of the Air Registration Board in place of Captain M. J. R. Alderson, whose term of service has recently expired.

KELVIN AND HUGHES, Ltd., states that Mr. F. W. Bates, general works manager, has been appointed a director. Mr. F. A. King and Mr. A. J. Hughes have retired from the board, each having spent about sixty years in the company's service.

THE EXPANDED METAL COMPANY, Ltd., Burwood House, Caxton Street, London, S.W.1, states that Mr. Frank Banfield, general manager, has been appointed managing director. He succeeds Lieut.-Commander G. C. Hans Hamilton, who continues as chairman of the company.

G. AND J. WEIR, Ltd., Cathcart, Glasgow, announces the appointment of executive directors as follows :—Hon. J. Kenneth Weir (chairman), Mr. J. Russell Lang, Mr. Harold Hillier, Mr. John Davidson, Mr. J. W. Atwell, Mr. I. G. Craig, Mr. J. J. B. Young, and Mr. D. C. Hagen.

MR. H. E. HARD has been appointed comptroller and secretary-director of International Harvester Company of Great Britain, Ltd., 259, City Road, London, E.C.1. He succeeds Mr. C. A. Wright who has returned to the U.S.A. to an appointment with the International Harvester Company, Chicago.

THE SOCIETY OF CONSULTING MARINE ENGINEERS AND SHIP SURVEYORS announces that Mr. J. E. Church, the principal superintendent and naval architect of the South American Saint Line, has been elected president in succession to Mr. Gilbert Knowles.

MR. K. B. ALLAN has been appointed manager of the Glasgow office of Brookhirst Switchgear, Ltd., in succession to Mr. T. C. Paton, who has retired from that position. Mr. Paton will continue to represent Cantie Switches, Ltd., in Scotland. Both companies are members of the Metal Industries, Ltd., group.

THE NATIONAL COAL BOARD states that Mr. J. Norval, deputy director of the general branch of the headquarters marketing department, is to become chairman of the South-Eastern division, on June 1st, in succession to Rear-Admiral (S.) H. R. M. Woodhouse, C.B. Mr. E. H. Browne is to succeed Mr. I. W. Cumberbatch as chairman of the West Midlands division, and Mr. H. A. Longden will follow Mr. Browne as director-general of production at the Board's headquarters. Mr. J. I. Willis has become deputy director-general (sales) in the headquarters marketing department, in place of Mr. R. H. E. Thomas, who was recently appointed a member of the National Coal Board.

Business Announcements

RENOLD CHAINS, Ltd., Wythenshawe, Manchester, has acquired the whole of the share capital of the Anchor Chain Company, Ltd., Oldham.

THE NATIONAL SMOKE ABATEMENT SOCIETY has moved its offices to Palace Chambers, Bridge Street, London, S.W.1 (telephone, Trafalgar 6838).

FINNEY PRESSES, Ltd., states that it is to manufacture under licence in this country vulcanising machinery produced by Davis-Standard Sales Corporation, Mystic, Connecticut, U.S.A.

BROOKHIRST SWITCHGEAR, Ltd., states that Arthur Trevor Williams (Pty.), Ltd., 16, Burlington House, Rissik Street, Johannesburg, is acting as its sole selling agent in South Africa, the Central African Federation and Portuguese East Africa.

HAMWORTHY ENGINEERING, Ltd., states that the first section of its new factory at Fleets Corner, Poole, Dorset, is to be opened on April 30th. The new factory, which occupies a 20-acre site on the outskirts of Poole, consists of four bays, each 180ft long, and a three-storey administrative block. The company's oil burning and hydraulics divisions will be housed in the new factory, and the pump and compressor division will operate from the existing factory at Hamworthy.

Miscellanea

BRITISH COAL UTILISATION RESEARCH.—The British Coal Utilisation Research Association is to hold open days at its laboratories, at Leatherhead, Surrey, on June 8th, 9th and 10th. The first day will be reserved for members of the Association, and on the two following days the laboratories will be open to visitors from professional organisations, public authorities, other research associations and schools.

INCORPORATED PLANT ENGINEERS.—The eighth annual conference of Incorporated Plant Engineers is to be held at the Hotel Majestic, St. Annes on the Sea, from May 18th to 20th. The general theme of the conference is " Plant, People and Prosperity," under which title an introductory address will be given by Mr. E. E. Button. Mr. G. Sievewright, the newly elected president, will deliver his address on the morning of May 19th.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—At the general meeting of the Institution, held on April 15th it was announced that Mr. P. L. Jones had been re-elected as president and that Mr. J. L. Batey and Mr. J. B. Woodeson had been elected as vice-presidents. Those elected as ordinary Members of Council were Messrs. A. T. Bowden, N. Carter, W. Muckle, R. J. W. Rudkin and H. P. Urwin (Non-Associates' Section), and W. J. Fleming (Associates' Section).

EUROPEAN FAIR AT STRASBOURG.—The Thirtieth European Fair to be held at Strasbourg will take place from September 3 to 18, 1955. The second largest trade fair in France, it will be housed in twenty-five halls on a 50-acre site at Wacken. Last year, it is stated, there were 2561 French and 724 foreign exhibitors, and an average daily attendance of over 45,000 was reached. Full information may be obtained from the Public Relations Officer, R. C. Liebman, 178, Fleet Street, London, E.C.4.

LAMINATED DENSIFIED WOOD.—A film entitled " From Strength to Strength " was recently shown in London. Made on behalf of Permali, Ltd., of Bristol Road, Gloucester, it illustrated the manufacture of resin-impregnated, densified wood laminates, as carried out at Gloucester, at the Haddenham factory of Hordern-Richmond, Ltd., and at Grenoble and other centres abroad. A great variety of uses of this mechanically strong and moisture-proof insulating material were given including, besides many of the better-known, and some unusual, applications in electrical engineering, such mechanical items as rolling mill bearings, connecting links and hangers for coal and coke shaker screens, and components of textile machinery.

OXIDATION OF METALS.—A summer school on the " Oxidation of Metals " is to be held at the Battersea Polytechnic, London, from July 19th to 22nd. The aspects of the subject to be considered include : theoretical principles of dry corrosion and anodic oxidation, oxidation and scaling of heat-resisting steels, alloys for electrical heating elements, nickel-base alloys for high-temperature use, oxidation resistance of the rarer metals, diffusion coatings for resistance to oxidation, and the effect of gases on high-temperature oxidation. In addition to the lectures, there will be discussions on the theoretical and practical aspects of oxidation, a demonstration and exhibition, a film show and a works visit. The fee for attendance at the school is £3 3s.

LLOYD'S WRECK RETURNS.—Lloyd's Register of Shipping has issued its return of merchant ships totally lost, broken up, &c., for the quarter ended September 30, 1954. Steamships and motorships lost consequent upon casualty totalled thirty-two ships of 35,369 tons gross throughout the world, a total which included three ships of 1569 tons belonging to Great Britain and Northern Ireland and four ships of 1355 tons owned by the other Commonwealth countries. The world total of steamships and motorships which were lost not consequent upon casualty amounted to ninety-nine ships of 346,074 tons gross and the total for Great Britain and Northern Ireland was thirty-three ships of 91,726 tons, while that for the other Commonwealth countries was nine ships of 22,192 tons.

TENTH INTERNATIONAL FAIR AT GHENT.—The Ghent International Fair will take place this year from September 10th to 25th. Since it was first held in 1946 the Ghent Fair has grown to be the second largest fair in Belgium. It was attended last year by 1213 exhibitors, of whom 555 were from abroad, and visited by 459,000 people. It is a general trade fair, which this year will include the second Printing, Paper and Allied Trades Exhibition, the first International Exhibition of Photography, Cinema Projection and Television, and the first International Exhibition of Laboratory Equipment. There will also be a substantial colonial section, mostly devoted to the Belgian Congo. Full details may be obtained from the London representative, Mr. R. C. Liebman, 178, Fleet Street, E.C.4.

GRINDING MACHINE MANUFACTURE.—A film dealing generally with the manufacture of precision grinding machines at the Leicester works of A. A. Jones and Shipman, Ltd., was shown in London last week. This film is entitled " To Be Precise," and it follows the manufacturing sequences from the drawing board to the final assembly and inspection of typical grinding machine components. The high degree of precision called for in all stages of production is emphasised and graphically described with reference to the plant, jigs and tools used to produce parts to very close tolerances. The film is the first of a series to be produced, each of which will deal with the construction, maintenance and operation of the surface, cylindrical, universal and tool and cutter grinding machines made by the firm.

CITY AND GUILDS FELLOWSHIPS.—The City and Guilds of London Institute has recently conferred fellowships upon the following past students :—Mr. A. McLeod Mooney, M.I.E.E., deputy director of electrical engineering, Admiralty ; Sir Ralph Reed, lately chairman of Albert E. Reed and Co., Ltd., paper manufacturers ; Dr. E. H. Rodd, formerly of Imperial Chemical Industries, Ltd.; Mr. N. E. Rowe, M.I.Mech.E., technical director of Blackburn and General Aircraft, Ltd., and Mr. C. W. Speirs, M.I.E.E., formerly with the Morgan Crucible Company, Ltd.

WROUGHT TITANIUM.—A booklet entitled " Wrought Titanium " has just been published by Imperial Chemical Industries, Ltd. In the introduction it is pointed out that titanium is commercially a very new metal and the publication is essentially a preliminary exposition as the present state of knowledge is inevitably incomplete. The material has certain very desirable properties and also limitations, some of which may disappear as fundamental and practical knowledge on the subject accumulates. For this reason further editions of the book will be published on new developments to keep the information on the subject as up to date as possible. The book first deals with the background of titanium and its nomenclature, and it then goes on to deal in some detail with its physical and mechanical properties. Sections are devoted to the future development of titanium alloys, resistance to corrosion, machining, forging, cold working and welding.

" LIGHTING AND THE ARCHITECT " EXHIBITION.—An exhibition entitled " Lighting and the Architect " was opened on April 18th at the Mazda showrooms of the British Thomson-Houston Company, Ltd., at Crown House, Aldwych, London, W.C.2. It shows how lamps, fittings, and control gear are designed to combine with the many other materials and products used in building. Flexibility in design is demonstrated by the series of Mazda " Module " fittings which may be interchanged with standard ceiling panels. The principle of standardisation is also applied to fluorescent lamp equipment in the " basic power pack " design where the gear channel provides the base for any one of a number of reflectors. An illuminated ceiling of washable corrugated plastic material is shown. Lastly, there is a model demonstrating how openings for lighting fittings may be constructed in shell concrete roofs. The exhibition will be open daily except Saturdays and Sundays until the end of August.

MR. W. J. BARLOW.—We have learned with deep regret of the death of Mr. W. J. Barlow, which occurred at Brighton on April 8th. For the whole of his working life he was in the service of George Reveirs, Ltd., the printers of THE ENGINEER. Mr. Barlow—or " Bob," as he was generally known to us and to his colleagues—joined our printers as a messenger in 1900, on the introduction of the late Mr. Vaughan Pendred, who was then the editor-in-chief of this journal. Soon afterwards, Mr. Barlow began an apprenticeship in the house of Reveirs, and thereafter worked in the composing room, principally on the make-up and preparation for press of the pages of THE ENGINEER. In 1945, Mr. Barlow became overseer of the composing room, from which position he retired in October last. By then he had completed no less than fifty-four years' continuous service with our printers. His loyalty to and valuable assistance in the regular production of this journal over so long a period are gratefully remembered by the proprietors and by the editorial and publishing staffs.

JOINT METALLURGICAL SOCIETIES MEETING.—From June 1st to 18th there is to be a joint meeting in Europe of metallurgical societies. The Iron and Steel Institute, the Institute of Metals and the leading metallurgical societies in Belgium, France, Germany and Sweden are responsible for the arrangements, and invitations to participate in the meeting have been accepted by the American Institute of Mining and Metallurgical Engineers and the American Society for Metals. The meeting will begin in London on June 1st, and at an open plenary session on that day Sir Lawrence Bragg, F.R.S., will deliver a lecture on " X-Ray Analysis and the Structure of Metals." The programme for June 1st to 7th includes sessions for the discussion of papers, visits to works and other places of interest in or near to London, and tours to metallurgical areas of Great Britain. Between June 8th and 18th tours to Germany and France are being organised, and, following the main meeting, tours are being arranged to other European countries, including Austria, Italy, Spain and Switzerland.

TUNNELLING RECORD.—A tunnelling record is announced by the contractors, Marples Ridgway and Partners, Ltd., engaged on the North of Scotland Hydro-Electric Board's Allt-na-Lairige project. The previous claim was 428ft driven in one week. Working twelve-hour shifts, a nine-man team advanced the face a distance of 444ft through granite in the 8ft by 6ft 6in tunnel forming part of this project, during the seven days commencing March 31, 1955. It is stated that a short working cycle was achieved by close attention to drilling speed, gas clearance and to loading out the broken rock. Holman drilling equipment was used, and three machines, drilling a twenty-one-hole pattern 8ft deep. The face air pressure was 115 lb per square inch, giving an average penetration rate in the granite of more than 20in per minute. One Eimco loader was used with an experimental shuttle car designed by the contractors to take the complete muck pile, thus eliminating car changing. Car dimensions were 70ft long by 4ft 6in by 4ft 6in. The sixty-seven cycles completed gave an average pull of 6ft 9in and of the cycle time, drilling took thirty-five minutes, charging twenty minutes, ventilation ten minutes, and mucking-out forty minutes.

British Patent Specifications

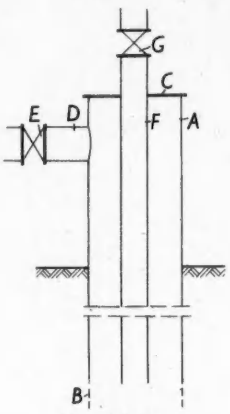
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 2s. 8d. each.

MINING ENGINEERING

725,611. May 11, 1953.—MAINTAINING AND RESTORING THE PRESSURE IN OIL AND GAS FIELDS, Union Rheinische Braunkohlen Kraftstoff Aktiengesellschaft, Wesserling, Germany, and Otto Kriegbaum, 68, Ludwigstrasse, Fürth (Bavaria), Germany.

In accordance with the invention, the pressure in oil and gas fields can be maintained or restored by generating an inert gas in the productive formation by combustion of natural gas or oil with oxygen-containing gases or compounds splitting off oxygen. The inert gas thus generated forces the petroleum to the surface by gas lift. The inert gas is injected under a pressure higher than that of the natural gas, say 100 atmospheres. In the drawings, *A* is the well casing, which is perforated at its lower end *B* and tightly sealed with a top plate *C*. The casing has on one side a short pipe *D* which can be closed by



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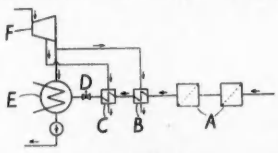
a shut-off device *E*. Smaller tubing *F*, which can be closed with a shut-off device *G*, is a tight fit through the plate and is led to the lower end of the casing. An inert gas supplied through the device *G* leaves the tubing *F* at its lower end, flows partly into the surrounding gas reservoir and partly in an upward movement in the space formed by the tube *F* and the casing *A*, and is released through the pipe *D* until the issuing gas no longer contains any combustible constituents. Compressed air is then injected through the shut-off devices *E* and/or *G*. A limited quantity only of inert gas is required to clean a well by the process described.—*March* 9, 1955.

POWER PLANTS

726,418. December 7, 1953, REMOVING GASES FROM FEED WATER, Sulzer Frères, Société Anonyme, Winterthur, Switzerland.

The invention relates to the removal of gases from feed water in steam plants, by pressure reduction which causes dissolved or occluded gases in the feed water to be released. In the system shown in the



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drawing there is a salts removal plant *A*, which operates on the ion exchange principle, employing two ion exchange beds. The purified water then passes through two preheaters *B* and *C* and a pressure reducing valve *D*, before entering a condenser *E*. The pure water coming out of the ion exchange plant *A* is generally so cold that the pressure drop to which it is subjected on entering the condenser would not be sufficient to release all the included gas. The pure water is therefore preheated in *B*, using exhaust steam from a turbine *F*, and then in a further preheater *C* in which its temperature is raised still higher by steam tapped off from the turbine. In this way the heat content of the water is increased to such an extent that when it is admitted to the condenser the harmful gas inclusions are completely removed. Instead of using exhaust steam or tapping off steam from the turbine, any other suitable heating medium could be used—for instance, stuffingbox steam or water blown down from the boiler, if it is sufficiently hot. An alternative system is also shown in the specification.—*March* 16, 1955.

BEARINGS AND SUPPORTS

726,182. February 26, 1952.—PLAIN BEARINGS, The Glacier Metal Company, Ltd., 368, Ealing Road, Alperton, Wembley, Middlesex. (*Inventors: Phil Prince Love and William Henry Tait.*)

It has been found that the addition of tin, with or without lead, to aluminium in quantities in excess of 4 or 5 per cent improves the surface qualities, and that with the addition of about 20 per cent of tin or lead, the surface properties are very good indeed. According to the invention, an aluminium alloy bearing liner is anodised externally to a depth which is substantial in relation to the wall thickness to provide the requisite increase in yield strength. The depth of anodisation may be from about one-tenth of the total thickness to about one-fifth. Thus, in bearing liners of the kind referred to having a usual wall thickness of from 0·080in to 0·160in, the anodised layer will extend to a depth of at least 0·008in, and may vary from 0·008in to 0·030in, according to wall thickness. Any suitable conventional anodising process may be employed, and it has been found that deep anodising of the outer layer or stratum of the liner increases the yield strength in compression, and two special methods of anodising are described and illustrated in the specification.—*March* 16, 1955.

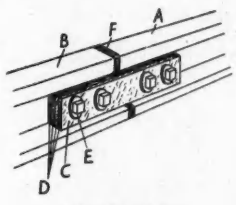
RAILWAY ENGINEERING

726,488. July 7, 1953.—INDUCED DRAUGHT FANS FOR LOCOMOTIVES, Henschel and Sohn G.m.b.H., 2, Henschelstrasse, Kassel, Germany.

The present invention aims at obviating or protecting induced draught fans for locomotives from wear by solid particles. According to the invention, sheet metal baffles are built into the smokebox upstream of the fan in such a position as to effect a sharp diversion of the flue gas current. The solid particles entrained in the flue gas are for the most part separated by the baffle or deflecting action of the baffles before the flue gases reach the fan. The accumulating mixture of ash, cinder and coal may be extracted by a steam or air-operated ejector and/or by mechanical conveyor means, such as a worm conveyor, and delivered downstream of the fan as desired, either into the waste gas pipe to the smoke stack or returned to the firebox where the particles having a high coal content are further burned. In the latter case, the separated particles are preferably supplied to the firebox at the front firebox wall beneath the fire screen. In this way, the fan is protected against premature wear.—*March* 16, 1955.

726,310. November 20, 1953.—BUTT JOINTS FOR RAILS, Hans Stager, Grutlistrasse 50, Zurich, Switzerland.

The invention provides a rail butt joint comprising insulating fishplates screwed to the rail ends to connect them together, and is characterised by the fact that there is set between the end faces of adjacent rails a plate assembly comprising two metal plates and an inter-layer of electrically insulating synthetic



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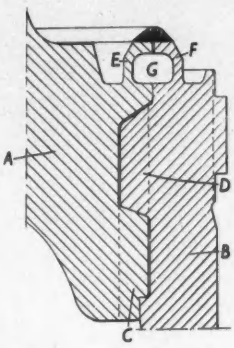
resin material which adheres firmly to the plates and joins them together. As will be seen from the drawing, the two rails *A* and *B* are connected together by a fishplate *C* consisting of a number of layers *D* of an insulating material—for example, a compressed laminated wood. The coupling is made by means of bolts *E*, which require no insulation. Between the end faces of the rails is a plate assembly *F* which comprises outer plates of metal and an intermediate layer made from synthetic materials or combinations of synthetic materials.—*March* 16, 1955.

VALVES

725,963. March 3, 1953.—VALVE CASINGS, Dewrance and Co., Ltd., Great Dover Street, London, S.E.1.

The invention relates to valves and particularly to valve casings suitable for use with high-pressure steam. As shown in the drawing, a circular closure member in the form of a cover *A* is inserted in the top of a cylindrical valve casing *B*, the cover and casing being formed with a bayonet joint. The cover has two diametrically opposite peripheral projections *C*, each of which subtends an angle of approximately 90 deg., whilst within the valve casing are formed two diametrically opposite projections *D*, each subtending an angle of approximately 90 deg. and respectively located immediately above the projections *C*. The projections *C* and *D* serve to lock the cover *A* in position on the valve casing. By rotating the cover through 90 deg. on the valve casing the projections *C* may be moved opposite the gaps between the projections *D* and withdrawn from the valve casing. In the drawing the cover is formed with a lip *E* and the



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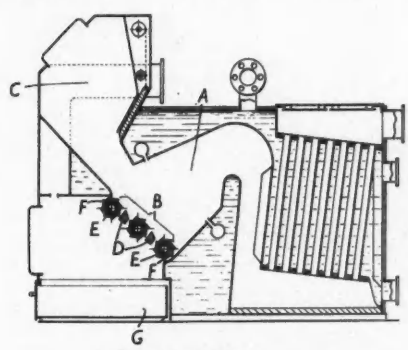
valve casing is formed with a lip *F*. The lips are curved towards one another so that they enclose an annular space *G*. The lips have flat upper surfaces and are joined by a weld seam. The thickness of the lips *E* and *F* is determined by considerations of safety. They are, however, resilient and the weld seam should be of such thickness as to ensure that stresses are not taken up by the weld alone, but approximately evenly by the lips and the weld. A modified form of joint is also shown in the specification.—*March* 16, 1955.

FURNACES

726,299. September 2, 1953.—STEPPED GRATE FOR FURNACES, Moring and Steenaart, N.V., Stationsweg 22, Nijkerk, Holland.

The drawing shows a longitudinal section of a water boiler having a built-in furnace designed to burn lumpy solid fuel. Referring to the drawing, the furnace *A* is provided with an inclined grate *B*, the upper side of which merges with the bottom of a fuel hopper *C*, which is inclined in the same direction as



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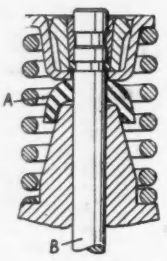
the grate. The grate is composed of stationary grate bars *D*, which alternate with parallel grate bars, each consisting of a stationary internal tube *E*, on which rotates a cylindrical drum *F*. The outer circumference of the drum is provided with longitudinal ribs having relatively sharp edges. The drums *F* are all coupled to a driving means by which they can be rotated. The tubes *E* and the grate bars *D* are hollow and are connected to the boiler below the water level, so that when the furnace is in operation the grate is cooled. During the operation of the boiler plant the fuel will roll under its own weight on to the grate *B* and there be burned. The slag which finds its way to the grate via the bed of fuel is sufficiently cooled and on being engaged by the teeth of the rotatable grate bars is crumbled and discharged via the grate to the ashpit *G*. The clinker which may land on the stationary grate bars *D* will slide down under its own weight to within the sphere of operation of the adjacent rotatable grate bar. Since the formation of clinker greatly depends on the intensity of the combustion, it is desirable to control the speed of revolution of the rotatable grate bars. This can be achieved in a simple manner by having the means for driving the undergrate blower also drive the rotatable bars. Thus, if the undergrate blower, under the control of a thermostat, is driven more or less rapidly, the combustion and the operation of the rotatable grate bars will be influenced correspondingly.—*March* 16, 1955.

INTERNAL COMBUSTION ENGINES

725,899. July 31, 1953.—VALVE STEM SEALS, The Ford Motor Company, Ltd., 88, Regent Street, London, W.1.

To prevent the leakage of oil or other liquid around the valve of an internal combustion engine, a seal of elastic material *A* is provided on the stem of the valve *B*, as shown in the drawing. The seal comprises



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a base with a flared skirt. The hole in the base is somewhat smaller than the diameter of the valve stem. In assembling the stem is thrust through the valve guide until the head is on the valve seat. The seal is then forced over the valve stem and pushed down till it meets the top of the valve guide, after which the remaining valve mechanism is assembled. When the valve is opened for the first time the seal is forced down the stem so that it is just in contact with the top of the valve guide when the valve is fully opened. Having assumed that position the seal moves only with the valve stem, and there is no relative motion. No excessive overhang of the seal is necessary, and no fine clearances have to be maintained between the seal and the valve guide. The generous clearances which are provided in the closed position of the valve allow sufficient oil mist to gather to lubricate the valve stem, but do not allow droplets of oil to run down the stem and penetrate the working space between the valve and the valve guide.—*March 9, 1955.*

Launches and Trial Trips

LONDON INTEGRITY, oil tanker ; built by the Furness Shipbuilding Company, Ltd., for London and Overseas Freighters, Ltd.; length overall 556ft 5in, length between perpendiculars 525ft, breadth moulded 71ft, depth moulded 39ft 3in, draught 30ft 6in, deadweight 17,930 tons ; twenty-seven cargo oil tanks, two pump rooms, four 500 tons per hour horizontal steam cargo oil pumps, two 150 tons per hour stripping pumps ; two 60kW steam-driven generators ; N.E.M.-Doxford single-acting, two-stroke, opposed-piston oil engine, six cylinders, 670mm diameter by 2320mm combined stroke, 6800 b.h.p. at 119 r.p.m., two Scotch boilers, trial speed 15 knots. Trial, March 29th.

PLUVOISE, oil tanker ; built by Ateliers et Chantiers de la Seine-Maritime for Compagnie Nationale de Navigation ; length overall 560ft 6in, length between perpendiculars 538ft 1in, breadth moulded 73ft 8in, depth 40ft 6in, draught 30ft 8in, deadweight 19,800 tons ; two 500kW turbo-alternators, one 100kW diesel-driven alternator ; one set of Rateau-Bretagne double reduction geared turbines, 8900 h.p., steam supplied at 570 lb per square inch and 895 deg. Fah. by two water-tube boilers. Trial, March.

IPHIGENIA, oil tanker ; built by Chantiers Navals de la Cistat for the Shell Company of Indo-China ; length overall 553ft 5in, length between perpendiculars 530ft, breath moulded 69ft 3in, depth 35ft, deadweight 18,300 tons, service speed 14·5 knots ; two 550kW turbine-driven alternators and one 200kW diesel-driven alternator ; one set of Parsons geared turbines built by Forges et Chantiers de la Mediterranee, 7500 h.p. at 100 r.p.m. or 8250 h.p. at 103 r.p.m. of propeller steam supplied by two water-tube boilers. Trial, March.

FERNVALLEY, open shelter deck cargo and passenger ship ; built by Alexander Stephen and Sons, Ltd., for Fearnley and Eger, Oslo ; length 400ft, breadth 57ft, depth 35ft, load draught 23ft, deadweight 6530 tons, gross tonnage 4550 ; twelve passengers ; seven watertight bulkheads, five cargo holds, a complement of 5-ton and 10-ton derricks, one 30-ton derrick, electric deck machinery ; three 180kW diesel-driven generators ; Stephen-Doxford two-stroke, opposed piston oil engine, four cylinders 670mm diameter by 2320mm combined stroke. Trial, March.

HERMES, oil tanker ; built by the Blythswood Shipbuilding Company, Ltd., for Bruusgaard, Kiosterud and Co., Norway ; length between perpendiculars 510ft, breadth moulded 68ft, depth moulded 38ft, dead weight 16,400 tons ; nine centre tanks, twelve wing tanks, two cargo pump rooms, four 400 tons per hour vertical steam cargo oil pumps ; Rowan-Doxford oil engine, five cylinders 700mm diameter by 2320mm combined stroke, 6200 b.h.p.; two single-ended boilers. Launch, April 7th.

OFF-SHORE FLOATING DOCK ; built by John Lewis and Sons, Ltd., for the Aberdeen Harbour Commissioners ; single-sided design, length overall 180ft, width overall 42ft 6in, depth of pontoon 7ft 6in, height of side wall 29ft 6in, depth over keel blocks 16ft, lifting capacity 700 tons, two 1560 tons per hour electrically driven centrifugal pumps. Launch, April 7th.

CAPETAN PSARROS, cargo ship ; built at the Neptune Works of Swan, Hunter and Wigham Richardson, Ltd., for the Tramp Chartering Corporation, Panama ; length between perpendiculars 450ft, breadth moulded 62ft, depth moulded to shelter deck 40ft 4in, deadweight 13,320 tons on 30ft 7¾in draught ; five cargo holds, ten 10-ton derricks, one 20-ton and one 30-ton derrick, electric winches, three 180kW diesel-driven generators, one 50kW diesel-driven generator ; one exhaust fired composite boiler and one oil-fired boiler ; Swan, Hunter-Doxford oil engine, five cylinders 670mm diameter by 2320mm combined stroke, 5500 b.h.p. at 115 r.p.m. ; trial speed 15½ knots. Trial, April 5th.

POLYNESIEN, passenger and cargo ship ; built by Chantiers Dubigem for Messageries Maritimes ; length overall 343ft 10in, length between perpendiculars 319ft 8in, breadth moulded 49ft 3in, depth moulded to upper deck 26ft 3in, draught loaded 17ft 9in, deadweight 2400 tons, service speed 15·5 knots ; 36 passengers ; three 200kW diesel-driven generators, Burmeister and Wain diesel engine, six cylinders, 620mm diameter by 1150mm stroke, 3600 h.p. at 150 r.p.m.

CHAMBORD, oil tanker ; built by Chantiers de France for Société Maritime des Pétroles B.P.; length overall 669ft 4in, length between perpendiculars 630ft 9in, breadth moulded 86ft, depth 46ft 8in, draught loaded 35ft 1in, deadweight 32,650 tons, load displacement 42,440 tons, gross tonnage 21,800 ; thirty cargo oil tanks, one pump room ; two 1000 tons per hour cargo oil pumps ; two 500kW turbine-driven alternators, one 75kW diesel-driven alternator ; C.E.M.-Parsons double reduction geared turbines, maximum h.p. 15,200 at 108 r.p.m., 14,000 service h.p. to give service speed of 16·4 knots, steam supplied at 600 lb per square inch and 850 deg. Fah. by two Penhoët-built water-tube boilers. Trial, April.

Catalogues

ALLEN WEST AND CO., Ltd., Brighton.—Booklet on control gear for water pumping plant.

FAWCETT PRESTON AND CO., Ltd., Bromborough, Cheshire.—Publication illustrating and describing "Steelpact" workshop furniture.

ABINGDON KING DICK, Ltd., Tyseley, Birmingham, 11. —Two new publications describing the King Dick torque wrench and power drive equipment.

BRENTFORD TRANSFORMERS, Ltd., Kidbrooke Park Road, Kidbrooke, London, S.E.3.—Booklet illustrating and describing "Green Seal" transformers.

THE STANDARD AND POCHIN BROS., Ltd., Evington Valley Road, Leicester.—Publication No. 1648, describing the "Variform" pulley-mounted centrifugal fan.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

BRITISH INSTITUTION OF RADIO ENGINEERS

Wed., April 27th.—LONDON SECTION : School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, S.W.1, "Suppressed Aerials for the Aircraft H.F. Band," K. J. Coppin, 6.30 p.m.——S. WALES SECTION : Cardiff College of Technology, Cathays Park, Cardiff, "Some Technical Problems in Sound and Television Broadcasting," K. R. Sturley, 6.30 p.m.

HULL CHEMICAL AND ENGINEERING SOCIETY

Tues., April 26th.—Church Institute, Hull, Annual General Meeting, 7.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

To-day, April 22nd.—BATH AND BRISTOL CENTRE : Royal Hotel, Bristol, Annual General Meeting, 6.15 p.m.——BIRMINGHAM CENTRE: Regent House, St. Phillip's Place, Colmore Row, Birmingham, "The Design and Application of Flameproof Lighting Equipment," D. A. Strachan, 6 p.m.

Mon., April 25th.—LEICESTER CENTRE : E. Midlands Electricity Board, Charles Street, Leicester, "Lamps and Lighting for Inspection," H. E. Bellchambers, 6 p.m.

INCORPORATED PLANT ENGINEERS

Mon., April 25th.—W. AND E. YORKSHIRE BRANCH : The University, Leeds, "Admiralty Salvage," W. D. Miller, 7.30 p.m.

Thurs., April 28th.—SHEFFIELD AND DISTRICT BRANCH : Grand Hotel, Sheffield, Papers by Members, 7.30 p.m.

Fri., April 29th.—BIRMINGHAM BRANCH : Imperial Hotel, Temple Street, Birmingham, "Locomotive Testing," 7.30 p.m.

Tues., May 3rd.—LONDON BRANCH : Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2, "Heat Pumps and Refrigeration," Sir Oliver Lyle, 7 p.m.

Wed., May 4th.—LEICESTER BRANCH : College of Art and Technology, The Newarkes, Leicester, "Selection of Electric Motors," K. Broom, 6.30 p.m.——SOUTHAMPTON BRANCH : Polygon Hotel, Southampton, Selected Films, 7.30 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

Sat., April 23rd.—LANCASHIRE BRANCH : Engineers' Club, Albert Square, Manchester, Annual General Meeting and Election of Officers, followed by John Wilkinson Memorial Medal Presentation and Winning Paper in the Short Paper Competition and "Foundry Brains Trust," 3 p.m.——W. RIDING OF YORKS. BRANCH : Technical College, Bradford, Annual General Meeting and Election of Officers, followed by Junior Prize Winning Award, 6.30 p.m.

Wed., April 27th.—BIRMINGHAM BRANCH : James Watt Memorial Institute, Great Charles Street, Birmingham, Annual General Meeting, "Developments in Mould and Core Making Processes, with Special Reference to the 'D Process' of Shell Moulding," A. Tipper, 7.15 p.m.

Thurs., April 28th.—SOUTHAMPTON SECTION : Technical College, St. Mary's Street, Southampton, Annual General Meeting, "Semi-Continuous Casting of Bronze," E. C. Ellwood, 7.30 p.m.

INSTITUTE OF MARINE ENGINEERS

Mon., April 25th.—STUDENT LECTURE : 85, Minories, London, E.C.3, "Safety at Sea," Stewart Hogg, 6.30 p.m.

Tues., April 26th.—85, Minories, London, E.C.3, Annual General Meeting, 5.30 p.m.

INSTITUTE OF REFRIGERATION

Thurs., May 5th.—Institution of Mechanical Engineers, 1, Birdcage Walk, Westminster, London, S.W.1, "Some Problems in the Design of Household Refrigerators," N. F. T. Saunders, 5.30 p.m.

INSTITUTE OF WELDING

To-day, April 22nd.—BIRMINGHAM BRANCH : Midland Institute, Paradise Street, Birmingham, "High Frequency Heating," K. A. Zandstra, 7.30 p.m.

Thurs. to Sat., April 28th to 30th.—The University, Nottingham, Spring Meeting, Technical Sessions and Works Visits.

INSTITUTION OF CHEMICAL ENGINEERS

Tues., April 26th.—May Fair Hotel, Berkeley Street, London, W.1, Thirty-Third Annual Corporate Meeting and Annual Dinner.

INSTITUTION OF CIVIL ENGINEERS

Tues., April 26th.—ORDINARY MEETING : Great George Street, Westminster, London, S.W.1, "Potentialities of the British Railways System as a Reserved Roadway System," T. I. Lloyd, 5.30 p.m.

Fri., April 29th.—YORKSHIRE ASSOCIATION : Great Northern Hotel, Leeds, Annual General Meeting, "Geophysical Surveying Applied to Geological and Engineering Problems," J. T. Whetton, 7 p.m.

Tues., May 3rd.—PUBLIC HEALTH MEETING : Great George Street, Westminster, London, S.W.1, "The Application of Prestressed Concrete to Water-Supply and Drainage," R. H. Evans, 5.30 p.m.

Thurs., May 5th.—N.W. ASSOCIATION : Engineers' Club, Albert Square, Manchester, Annual General Meeting, 6.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

To-day, April 22nd.—EDUCATION DISCUSSION CIRCLE : Savoy Place, London, W.C.2, Discussion on "Technical Training in N.W. Germany," opened by K. R. Sturley, 6 p.m.

Mon., April 25th.—LONDON STUDENTS' SECTION : Savoy Place, London, W.C.2, "The Training of Graduates," J. M. Armstrong, 6.30 p.m.

Wed., April 27th.—SUPPLY SECTION : Savoy Place, London, W.C.2, "Automatic Circuit Reclosers," G. F. Peirson, A. H. Pollard and N. Care, 5.30 p.m.

Thurs., April 28th.—EXTRA MEETING : Savoy Place, London, W.C.2, "The Adhesion of Electric Locomotives," H. I. Andrews, 5.30 p.m.

Mon., May 2nd.—RADIO SECTION : Savoy Place, London, W.C.2, "A Simple Introduction to Telegraph Codes," H. V. Higgitt, 5.30 p.m.——S. MIDLAND CENTRE : James Watt Memorial Institute, Great Charles Street, Birmingham, "Fuel Supplies of the Future," E. F. Schumacher, 6 p.m.

Tues., May 3rd.—MEASUREMENTS SECTION : Savoy Place, London, W.C.2, "Medical Uses of Radioactive Isotopes," W. V. Mayneord, 5.30 p.m.——N. MIDLAND CENTRE : British Electricity Authority, 1, Whitehall Road, Leeds, 1, Annual General Meeting, 6.30 p.m.

INSTITUTION OF LOCOMOTIVE ENGINEERS

Wed., May 4th.—GENERAL MEETING: Institution of Mechanical Engineers, 1, Birdcage Walk, Westminster, London, S.W.1, "Operation and Running Maintenance of Locomotives on the Nigerian Railway," F. H. Jaekel, 5.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, April 22nd.—1, Birdcage Walk, Westminster, London, S.W.1, "Fuel Consumption and the Speed of Railway Transport," A. Gilmour, "An Experimental Turbo-diesel Locomotive," F. L. Picard, followed by Discussion, 5.30 p.m.

Tues., April 26th.—LONDON GRADUATES SECTION : 1, Birdcage Walk, Westminster, London, S.W.1, "Heat Transfer to Liquids Boiling in Tubes, with Particular Reference to Refrigeration Evaporators," R. J. Beale, 6.30 p.m.

Wed., April 27th.—EDUCATION GROUP : 1, Birdcage Walk, Westminster, London, S.W.1, Discussion, "The Most Effective Way of Obtaining Close Co-operation between Students and Teaching Staff," 6.45 p.m.——N.E. A.D. CENTRE : Chemistry Lecture Theatre, The University, Leeds, Address by Centre Chairman, J. L. Hepworth, 7.15 p.m.——SOUTHERN GRADUATES SECTION : Technical College, Brighton, "Some Problems in Commissioning and Operating Brighton 'B' Power Station," E. W. Ayling, 7 p.m.

Thurs., April 28th.—WESTERN A.D. CENTRE : Royal Hotel, Bristol, "Matching a Diesel to Light Road Vehicles," N. Vulliamy, 6.45 p.m.

Fri., April 29th.—GENERAL MEETING : 1, Birdcage Walk, Westminster, London, S.W.1, James Clayton Lecture, "The Transport Helicopter," Igor I. Sikorsky, 5.30 p.m.—— SOUTHERN GRADUATES SECTION : Technical College, Guildford, Annual General Meeting, Film Show, 7.30 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

Mon., April 25th.—MANCHESTER GRADUATE SECTION : Reynolds Hall, College of Technology, Sackville Street, Manchester, "From Diamond to Spark Machining," G. Fefer, 6.45 p.m.

Wed., April 27th.—SHREWSBURY SECTION : Technical College, Shrewsbury, "Manufacture of Springs," John A. Roberts, 7.30 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

Thurs., April 28th.—11, Upper Belgrave Street, London, S.W.1, "Colliery Structures," G. P. Bridges, 6 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, April 22nd.—INFORMAL MEETING : Pepys House, 14, Rochester Row, London, S.W.1, "Some Preliminary Notes on the 'Electronic Brain' in the Automatic Factory," W. J. Kease, 7 p.m.

REINFORCED CONCRETE ASSOCIATION

To-day, April 22nd.—MIDLAND COUNTIES BRANCH : James Watt Memorial Institute, Great Charles Street, Birmingham, "Recent Developments in the Technique of Precasting Concrete Structures," J. A. Derrington, 6 p.m.

ROYAL AERONAUTICAL SOCIETY

Tues., April 26th.—SECTION LECTURE : 4, Hamilton Place, London, W.1, "Aerial Systems for Aircraft," R. A. Burberry, 7 p.m.

Tues., May 3rd.—SECTION LECTURE : 4, Hamilton Place, London, W.1, "Plastic Structures," G. C. Hulbert, 7 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Mon., May 2nd.—ORDINARY GENERAL MEETING : 12, Great George Street, Westminster, London, S.W.1, "The City of To-morrow : Barbican and Beyond," Bryan Anstey, 5.30 p.m.

SOCIETY OF CHEMICAL INDUSTRY

Wed., April 27th.—CORROSION GROUP : Burlington House, Piccadilly, London, W.1, Annual General Meeting, "Some Thoughts on the Practice of Applied Science," J. C. Hudson, 6.30 p.m.